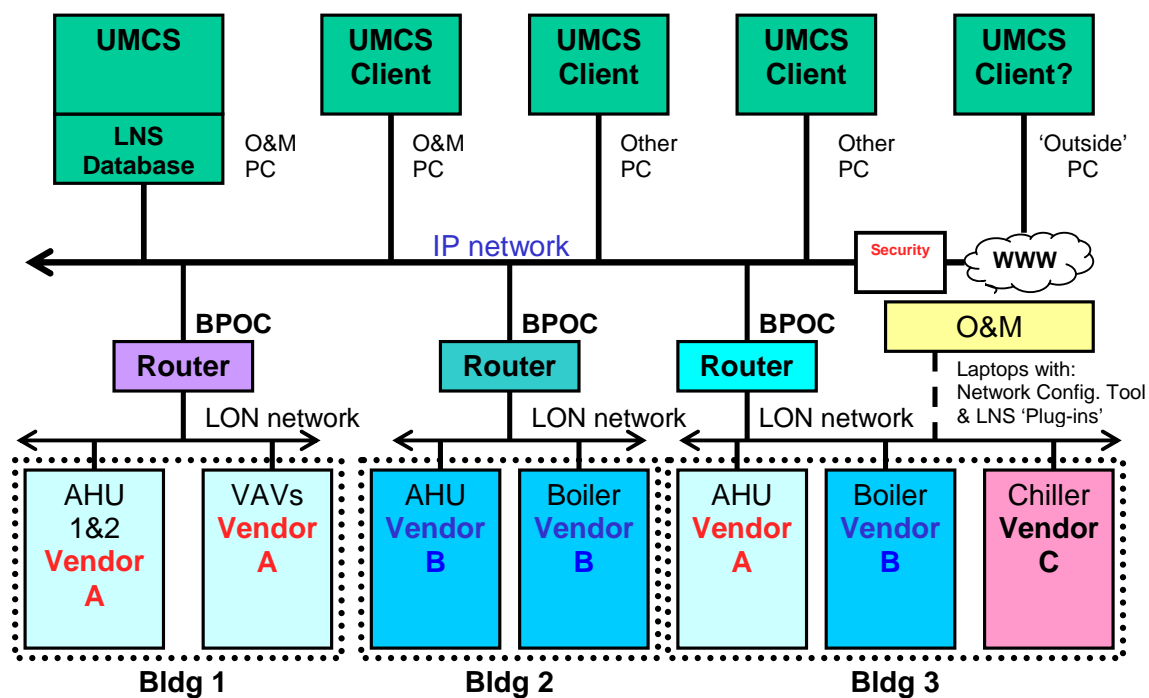Construction Engineering
Research Laboratory

US Army Corps
of Engineers®
Engineer Research and
Development Center

IMCOM LONWORKS® Building Automation Systems Implementation Strategy

Final Report

David M. Schwenk, Joseph Bush, Lucie M. Hughes, Stephen Briggs, and Will White

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IMCOM LᴏɴWᴏʀᴋs® Bᴜɪʟᴅɪɴɢ Automation Systems Implementation Strategy

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Abstract: Army Installations often expand their use of digital control systems for heating, ventilating, and air conditioning and other mechanical and electrical building systems on a building-by-building basis. Associated control systems are installed under separate contracts by different contractors resulting in intra-system incompatibilities. The implementation of multi-vendor Open Building Automation Systems (BASs) is meant to overcome such incompatibilities; however BASs can present their own technical and administrative (including contractual) challenges. This report defines a methodology for the development and execution of a basewide Open Building Automation System (BAS) implementation plan based on LONWORKS ® technology and American National Standards Institute (ANSI) communications standard 709.1 where the BAS consists of a basewide Utility Monitoring and Control System (UMCS) that is interoperable with multi-vendor LONWORKS ® direct digital control (DDC) systems.

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Preface

1 Introduction

1.1 Background

Army Installations are expanding their use of direct digital control (DDC) systems for heating, ventilating, and air-conditioning (HVAC) and other mechanical and electrical building systems, often on a building-by-building basis, in which the control systems are installed under separate contracts by different contractors resulting in incompatibilities between the separate systems. Significantly, these systems are often installed without the planning, preparation, training, and ground rules needed to obtain a functional, usable, expandable and (most notably), supportable system.

The implementation of multi-vendor Open Building Automation Systems (BASs) present both technical and administrative (including contractual) challenges. A Building Automation System (BAS), within the context of this document, includes one or more building-level DDC systems interoperating with a supervisory Utility Monitoring and Control System (UMCS) where the UMCS is used to monitor and manage the DDC systems. A long-standing goal of most Army installations is to implement a basewide BAS as opposed to multiple separate and independent BASs. A successful BAS is one that is functional, energy efficient, and cost effective.

More importantly, a BAS must support the needs of the building occupants, operations and maintenance (O&M) staff, and management. Even though industry standards and specification guidance are available, there are many potential pitfalls. The following Unified Facilities Guide Specifications (UFGSs) for BASs based on LONWORKS ® technology and American National Standards Institute (ANSI) standard 709.1 communications protocol were released in FY04:

- DDC Guide Specification. Unified Facilities Guide Specification (UFGS) 23 09 23 (previously UFGS 15951): Direct Digital Control for HVAC and Other Building Systems.
- UMCS Guide Specification. UFGS 25 10 10 (previously UFGS 13801): Utility Monitoring and Control System (UMCS)

These UFGSs were designed to address many open system pitfalls, but implementation challenges extend beyond the designer's ordinary realm of responsibility.

UFGS 23 09 23 (the DDC guide spec) specifies controls at the building level and UFGS 25 10 10 (the UMCS guide spec) specifies the supervisory and basewide system. These criteria were developed to help with the implementation of Open, non-proprietary, and interoperable multi-vendor DDC systems that integrate with a UMCS. The UMCS is intended to be a single system that serves as a basewide interface to the multi-vendor building-level DDC systems. The intent of both the DDC and UMCS guide specs is to specify and procure an Open system. In practice, the UMCS user interface software will be procured from a single vendor, although the specification is written to ensure the overall BAS remains Open. Figure 1 illustrates a UMCS/DDC system where multiple building DDC systems have been integrated into a single UMCS that provides multiple operator workstations ("UMCS Client"). Figure 2 also shows the UMCS/DDC system and distinguishes between the UMCS and DDC elements specified by the two guide specifications.

An Open system, in short, is one where there is no future dependence on the original installing Contractor. For the purposes of procurement, this means that there is no sole source dependence on any Contractor for future system additions, upgrades, or modifications. An Open system helps to avoid proprietary sole source procurement in accordance with Government procurement rules. In practice, single-source procurement of the integration of building-level DDC systems into the UMCS is valuable, but single-source procurement can and should be avoided for the building-level DDC systems. Methods for procuring and expanding the UMCS are discussed in Section 2.4 , "Identify building integration approach" (p 23). Related BAS implementation guidance and information is available in Engineering and Construction Bulletin (ECB) 2004-11, ECB 2005-17, ECB 2007-8, and ERDC/CERL Technical Reports TR-05-14 and TR-07-03. Additional information along with updates to the material contained in this report may be found at: https://eko.usace.army.mil/fa/bas/

1.2 Objective

The objective of this work was to define and document a methodology that will serve as a tool for the development and execution of a basewide Open BAS implementation plan based on LONWORKS ® technology and ANSI communications standard 709.1, where the BAS consists of a basewide UMCS that is interoperable with multi-vendor LONWORKS ® DDC systems.
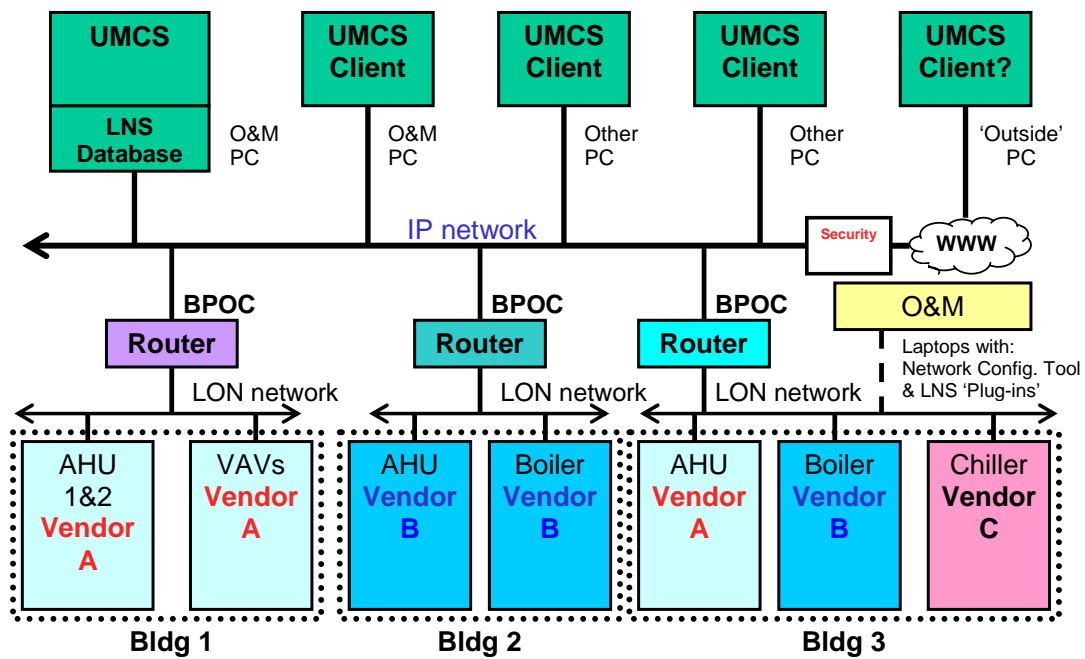
BPOC=Building Point of Connection (UMCS to Building Control Network)

Figure 1. Basewide LONWORKS ® BAS—including a UMCS and multiple-vendor DDC systems.
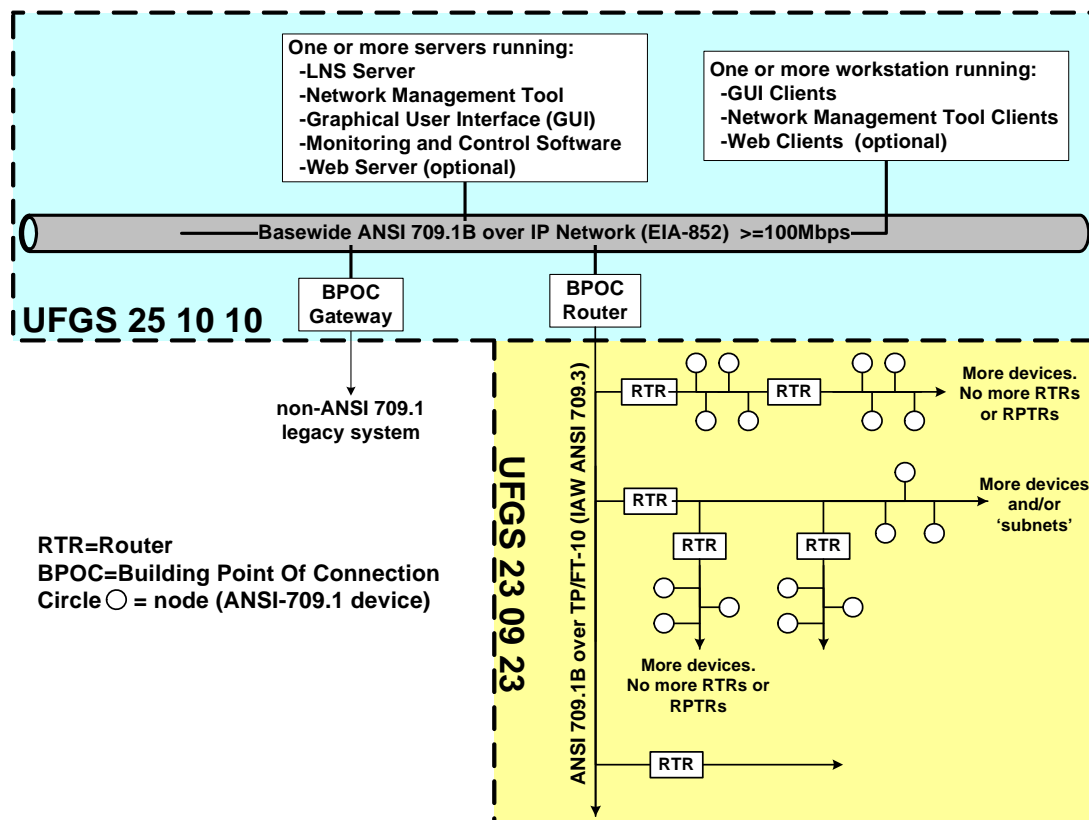
Figure 2. BAS comprised of UMCS and DDC systems.

1.3 Approach

The initial step of this project involved the creation and execution of an implementation plan for LONWORKS ® building automation systems, documented in this report. In coordination with Huntsville Mandatory Center of Expertise for UMCS and Savannah District Directory of Expertise for HVAC Control Systems, the strategy described in ERDC-CERL TR-07-16 was implemented over the course of FY07 at five Army installations: Fort Bliss, Fort Bragg, Fort Hood, Fort Lee, and Fort Sill. The lessons learned from field implementation at these installations have been incorporated into this report, which provides guidance on the development and execution of an implementation plan. The appendices to this report contain a variety of sample documents and templates (discussed in Chapter 2) prepared to aid installation planners in developing their planning, contracting, and execution documents:

- Appendix A: Control Systems Assessment Statement of Work (p 39)
- Appendix B: DOIM FAQ (p 47)
- Appendix C: DOIM MOU (p 52)
- Appendix D: Installation Design Guide Draft Verbiage (p 54)
- Appendix E: UMCS System Administrator, Tech Support Rep, and System Integrator SOW (p 58)
- Appendix F: UMCS DDC Integration SOW (p 70)
- Appendix G: DDC Integration Process via MIPR (p 75)
- Appendix H: Example Implementation Plan (p 78).
- Appendix I: LonWorks Compliance Assessment Tool (p 91).

1.4 Scope

This document provides guidance on the creation of an installation-specific building automation system implementation plan with an emphasis on the definition, specification, and procurement of an Open basewide UMCS. Limited guidance on the implementation of building-level DDC systems is included. Specifically, building-level DDC guidance focuses on those requirements that deal with system interoperability with the UMCS, overall system functionality, and maintainability. While this methodology is Army-specific, it may be generically suitable for use by other military and nonmilitary users. Similarly, while this methodology is specific to the implementation of LONWORKS based on the UFGSs, portions of it may be generically suitable for a BAS using a different technology or protocol.

1.5 Mode of technology transfer

This report will be made accessible through the World Wide Web (WWW) at URL: http://www.cecer.army.mil

2   BAS Implementation

Development and execution of a BAS Implementation Plan is the responsibility of the Installation. This development and execution can be accomplished using combination of internal and external resources, where external resources may be necessary to obtain technical assistance and UMCS procurement assistance. The following sequence of tasks and events describe the development of an integration plan and subsequent procurement of a basewide UMCS:

1. Assemble a BAS workgroup (Section 2.1 , following section)
2. Identify issues, goals, and obstacles (Section 2.2 , p 10)
3. Identify approach to address obstacles (Section 2.3 , p 13)
4. Develop statement(s) of work (SOW[s]) to obtain external technical assistance (Section 2.3.1 , p 14)
5. Coordinate with Directorate of Information Management (DOIM) (Section 2.3.2 , p 14)
6. Define/develop building acceptance methodology and checklists (Section 2.3.3 , p 21)
7. Define training requirements (Section 2.3.4 , p 22)
8. Develop Installation Design Guide (IDG) requirements and in-house LONWORKS® specs (Section 2.3.5 , p 23)
9. Identify building integration approach (Section 2.4 , p 23)
10. Develop UMCS System Administrator, Technical Support Representative, and System Integrator SOW (Section 2.4.5 , p 30)
11. Document implementation plan (Section 2.5 , p 31)
12. Execute UMCS procurement (Section 2.6 , p 33).

This sequence is not fixed. The individual tasks/events along with the order might vary depending on the installation's situation and needs.

2.1 Assemble a BAS workgroup

The Workgroup should minimally consist of:

- Energy Manager
- Chief of Directorate of Public Works (DPW) O&M
- DPW Shop and/or work leader

- DPW mechanic(s)
- Plans and Programs (P&P)
- DOIM and the Corps Area and/or Resident Engineer.

The Workgroup may also include the Corps District designer and external consultants such as Huntsville Center (HNC), Savannah District (SAS) and the Engineer Research Development Center Construction Engineering Research Laboratory (ERDC-CERL).

Not all members of the Workgroup need to be involved in the entire implementation plan development and execution process, but all members can be expected to contribute at various stages of plan development, and all members will benefit from the final plan. A statement of intent should be communicated to the Chief of DPW and the Garrison Commander through a memo, e-mail, or meeting since support of these individuals will be valuable to the successful development and implementation of the plan.

Generally, workgroup roles and responsibilities will be:

- *Energy Manager.* As the lead person responsible for energy conservation and ultimately responsible for operating and maintaining the BAS, at the installation, the Energy Manager will be primarily responsible for ensuring that the BAS functionality achieves the desired level of energy performance. This will require review of sequences of operation in the buildings, review of any installation-wide demand-limiting functionality, determination of metering requirements, and requests for installation of new hardware for energy efficiency. The Energy Manager should also ensure that any needed software or hardware tools required to perform O&M (e.g., laptops equipped with configuration software) is included with the procurement.
- *Chief of DPW O&M.* The Chief of O&M must ensure that the BAS can be supported by the DPW. This will require review of proposed sequences, control hardware, and front end functionality. Particular attention will be needed to ensure that the front-end user interface provides easy-to-use access to features the O&M staff deems essential. Finally, the Chief is responsible for ensuring that necessary training is provided and that O&M staff are available to participate in the training. DPW buy-in and ownership of the BAS is essential for a successful project.

- *DPW Shop Leader and Mechanics.* The advice and expertise of the individuals who will operate and maintain HVAC equipment operated by the BAS is critical. The maintenance staff ordinarily has a wealth of hands-on experience. They likely can also provide valuable input for defining training needs.
- *Plans and Programs.* In-house designs must be accomplished in accordance with the BAS Implementation Plan (described later) and resultant BAS requirements.
- *DOIM.* As the organization responsible for the basewide Information Technology Local Area Network (IT LAN), and in particular responsible for security on this LAN, the DOIM's role in supporting the BAS installation and in ensuring that the BAS meets Army requirements cannot be overstated. Their participation in the working group is absolutely essential for a successful BAS installation. Modern BASs require a basewide Internet Protocol (IP) network for operation (the basewide IT LAN is an IP network). Coordination with the DOIM in obtaining this IP network is essential. While modern BASs have many similarities to IT systems, which may raise red flags with the DOIM, there are also important differences that can mitigate their concerns; a well-informed DOIM is the best insurance against major roadblocks later in the installation process. For example, while the BAS as specified in UFGS 23 09 23 and UFGS 25 10 10 does not rely on HTML, Extensible Markup Language (XML), Web Services, or http, for communication between the front end and building controls (and in fact requires use of a different mechanism) some BAS vendors may include products using these protocols in their submittals, and thus coordination with the DOIM is needed to ensure that these products meet DOIM requirements or are rejected.
- *Corps Area and/or Resident Engineer.* The Corps Area and/or Resident Engineer is the party primarily responsible for system installation and commissioning, and for ensuring that the BAS meets the contract requirements and performs as specified. It is an unavoidable fact that Open System procurement and installation is more challenging than that of proprietary systems. Much of UFGS 23 09 23 and UFGS 25 10 10 is dedicated to communication issues/requirements; functionality that would just be "assumed to work" in a proprietary procurement. In addition, while UFGS 23 09 23 and UFGS 25 10 10 provide guide specifications, it is anticipated that designers will modify the specifications

due to project-specific requirements. For these reasons, it is important that the Area and/or Resident Engineer be involved in this process.

- *External Consultants*. Most Corps design offices are overworked, and as previously noted, Open System procurement will be more challenging than proprietary procurement. For this reason, and particularly in the initial phases, it can be beneficial to obtain outside expert assistance, such as can be obtained from the Huntsville Mandatory Center of Expertise (MCX) for UMCS, Savannah Directory of Expertise (DX) for HVAC Control, or the Engineer Research Development Center (ERDC). Other private consultants may be equally valuable. However at this time, few may have an in-depth familiarity with the guide specifications.

Finally, although not explicitly members of the Workgroup, the success of the BAS installation depends on several other individuals/organizations:

- *Chief of DPW*. The Chief of DPW can assist the Workgroup with advocacy across all DPW offices and well as between the DPW and DOIM, Job Order Contracts, P&P etc.
- *Garrison Commander*. A Garrison Commander who recognizes the value of a BAS that meets specifications can be a powerful advocate for getting a functioning BAS; the Garrison Commander's buy-in is critical.
- *Contracting Officer*. BAS Contracts can be challenging due to complex requirements and potentially burdensome contracting procedures such as the establishment of an indefinite delivery indefinite quantity (ID/IQ) contract for system integration/support services. The Workgroup should (and may already) recognize this challenge.
- *Building Tenants*. Occupants are often (understandably so) in a great hurry to move into a new/renovated building and often force beneficial occupancy before the BAS is complete. Occupants who understand the need for the BAS to function according to specification and can delay their move until the BAS is fully commissioned can become powerful champions of a successful BAS procurement. This frequently requires education of the tenants, whom seldom understand the impact of a dysfunctional BAS.
- *Corps District Designer*. Designs must be accomplished in accordance with the installation's BAS Implementation Plan and requirements while working within the framework of UFGS 23 09 23 and UFGS 25 10 10. Membership in the Workgroup is optional, but communication and coordination with the Corps District is essential.

2.2 Identify issues, goals, and obstacles

The Workgroup must address the current status of the installation's BAS(s). This includes creating lists of issues, goals and obstacles. These lists do not need to be rigorously detailed, but should be as complete as possible since they will be an important part of the final implementation plan for the BAS. Also, they are important to help identify any "broken" policies or procedures that need to be addressed. Of equal importance is for the group to recognize (and not waste time on) problems that the BAS will not solve; the BAS is not a panacea and will not solve systemic procurement, commissioning, financial, or O&M issues.

2.2.1 Identify issues

The first part of this step is to identify the main issues that exist with the current system or that the Workgroup feels might exist with future systems. This list of issues will be used to help identify the goals of the new BAS. Some issues commonly experienced by installations are:

- *Multiple BASs exist.* In some cases, installations have made the decision to maintain multiple independent BASs as a means to allow competitive procurement. In other cases, multiple BASs are a result of the procurement of incompatible systems. In either situation, it is generally more costly to maintain and expand multiple systems than a single system. Multiple BASs generally lead to the following specific problems:
  - o *Many O&M laptops that are not used.* This often occurs when systems from many manufacturers are installed and these software tools are provided with limited training. Without training in, and frequent use of these tools, skills deteriorate and the installation's ability to troubleshoot and manage its systems is hampered.
  - o *Too many front-end software packages.* There may be too many front-end computers when multiple BASs exist. Each system requires its own front-end interface and it takes several interfaces (software packages) to monitor the entire network. An installation may find it difficult to maintain training and skills on multiple front-ends, which often hampers its ability to effectively use the BAS systems.
- *Not enough front-end computers* At the other extreme, the installation may have no front-end computer or other operator interface at all.

These systems are extremely difficult to use and maintain since it is difficult to determine what they are doing.

- *Insufficient training.* The O&M staff is not adequately trained on the use and operation of the system.
- *Insufficient or superfluous BAS features.* The BAS includes features that are not needed and possibly confuse operators, or the BAS does not include features that are needed/desired by the installation (such as demand limiting).
- *Systems never worked.* Systems are accepted even though they are not functioning properly. This is a result of poor commissioning of the systems, which in turn can be due to:
  - Lack of time at the end of the project to adequately commission the systems (often due to delays earlier in the project and/or tenant-imposed deadlines for completion)
  - Specification of overly-complex systems i.e., systems beyond the technical expertise of the commissioning agents to adequately evaluate.
- *DPW not involved.* The DPW is not involved in the acceptance process for BASs so there is no sense of ownership by those that will have to maintain the system.
- *BASs are underused.* This usually occurs because the BASs are not properly configured to provide useful feedback to the operators, or is due to inadequate training. As a result, systems are generally operated in a "full manual" mode, with systems running 24/7 under fixed operating conditions. While systems operated in this manner may be configured to satisfy occupant comfort *or* to conserve energy, they *cannot* satisfy occupants *and* conserve energy.

2.2.2 Define goals

Once the Workgroup has identified issues with the current BAS, it should define goals that will address these issues. The primary goal addressed by this implementation plan guidance is that of obtaining Open Systems. i.e., that the building and UMCS systems shall be Open implementations of LONWORKS® in accordance with the DDC and UMCS guide specs. This goal helps address several, but not all, of the issues identified above. In particular, the open system goal largely eliminates problems due to multiple, incompatible proprietary systems. Other goals the Workgroup may wish to consider are:

- *System Capabilities.* Identify the required capabilities of the system. For example: monitor the building-level systems and generate an alarm when something is wrong, provide scheduled on/off capability for all primary equipment, and incorporate preventive maintenance features such as pump run time monitoring/logging.
- *Training and Support.* A successful UMCS will require a support structure and qualified staff. Identifying, establishing, and maintaining a balance of in-house and external support may be a challenge.
- *Client (Workstation) Type.* Some front end packages provide a web interface—sometimes as an option and sometimes as an integral part of the software. The Workgroup may wish to identify whether a web interface is desired and practical (e.g., whether there are DOIM requirements that either require it or prohibit it).

2.2.3 Rank goals

After identifying the goals, the Workgroup may choose to identify the relative importance of the goals. This list of prioritized goals can be used during the development of the source selection criteria for procurement of the UMCS and the System Integrator.

2.2.4 Identify obstacles

Once the goals for the system are identified the Workgroup should identify obstacles that might impact their ability to realize those goals. Some possible obstacles are:

- *Cooperation between DPW and DOIM.* These organizations will not necessarily agree on the best solution for the BAS. For example, DPW

might want a web-based front end while DOIM might not want another web server on the network.

- *Resources.* Is there sufficient expertise on the DPW staff or otherwise available to enable the installation to operate and maintain the system? In particular, there needs to be a long-term commitment of personnel to support and maintain the system.
- *Commitment of Management.* Management must make a long-term commitment to establishing a BAS that meets the Workgroup-established goals for these goals to be met.
- *Training Limitations.* To properly operate and maintain the system may require significant training. The amount of training time and funds available may impact the ability to train DPW staff to operate/maintain the system.
- *User Buy-in and Support.* The users (the DPW and maintenance staff) must buy-in to the system and support it for the Workgroup-established goals to be met.
- *Cost.* Systems meeting the implementation plan defined by the Workgroup may be more costly than other alternatives in the short term, but having a single coherent and working system will prove beneficial in the long term. If cost is the determining factor in awarding future construction, systems that are incompatible may be procured, e.g., if a contractor submits a "value engineering" proposal and it is awarded.

2.3 Identify approach to address obstacles

Once the Workgroup has identified obstacles that may hamper the execution of the plan, it should identify an approach to addressing these obstacles. In general, the obstacles will fit one of three categories:

1. *Fixable.* These are obstacles that the Workgroup can eliminate such as policies that the Workgroup can change (or get someone to change) or management buy-in that the Workgroup can obtain.
2. *Addressable.* These are obstacles that the Workgroup cannot change; however, they can work around the obstacles in some fashion such as by obtaining exceptions from policy or by including specific requirements to be met by the system.
3. *Unavoidable.* These are obstacles that the Workgroup cannot change or work around and must avoid. Policies that do not offer exceptions or hard limits on funding are two examples.

The Workgroup should identify the appropriate actions to remove, modify or avoid "fixable" and "addressable" obstacles and begin to resolve these issues. "Unavoidable" obstacles should be carefully documented and a means to avoid them should be identified.

2.3.1 Develop SOW(s) to obtain external technical assistance

The UMCS Workgroup should decide if external assistance is needed to proceed with development of the implementation plan and develop statements of work (SOWs) to obtain this assistance. In particular, external assistance may be helpful in performing a site survey to document the current state of the installation's BAS and DDC systems and prioritize buildings for integration to the new UMCS.

Appendix A (p 39) contains a sample SOW for this type of assistance. The Workgroup should feel free to add requirements to the SOW and/or to perform some of the work in-house. Should the Workgroup decide to pursue external assistance, it should consider contacting the local Corps District Office or the Huntsville Engineering and Support Center for possible contracting support.

2.3.2 Coordinate with DOIM

The BAS is dependent on an IP network and personal computers (monitoring and control (M&C) server(s), client workstations) for operation. This makes coordination with the installation Directorate of Information Management (DOIM) essential, for three main reasons:

1. On most installations, any computers and IP networking including hardware/devices connected to the network must be approved by the DOIM.
2. There are mandatory Army and Department of Defense (DOD) policies applicable to any Army information system (including the UMCS, and regardless of whether they utilize the basewide LAN). On most Army installations, compliance with these requirements can be extremely difficult without DOIM cooperation.
3. There are many IT issues associated with the BAS for which the DOIM will be the resident expert and can provide invaluable assistance. To just name a few:
    a.   Installation, operation, and maintenance of the IP network

      b.   Operation and maintenance of computer hardware (servers and work-stations)

      c.   Operation and maintenance of computer software. While the M&C software will be very application-specific (and outside DOIM's area of expertise), it generally depends on other software, such as operating system, database servers, web servers, browsers, etc., all of which are standard packages and should be supported by DOIM.

In addition, DOIM can provide insight into the availability and benefits of alternative networking options that provide promise for cost effective systems interfacing and integration. Wireless networking options (such as WiFi or radio) can be of particular value when integrating remote sites or sites with other restricted access to the LAN.

The first step in coordinating with the DOIM is to explain (in terms relevant to the DOIM) what the BAS is:

1.   The BAS will use two distinct networks:

      a.   Inside buildings, the local control network (as installed by the UFGS 23 09 23 contractor) will be a TP/FT-10 network[*] (shown in Figure 2) using the ANSI 709.1 protocol. This is a local control network operating at 78 kbps, not an IP network. The nature of this network does not allow it to be used as a launching point for attacks against the IP network and should therefore not be of concern to the DOIM

      b.   Outside the buildings, the BAS uses an IP network, ideally one based on fiber Ethernet, although any media supporting IP will work. This network may or may not be the same IP network as the DOIM maintained basewide LAN and is referred to at the UMCS Network (or the UMCS IP Network). While it is not **required** that the UMCS use the basewide LAN, its use is **strongly** encouraged as use of the basewide LAN will greatly facilitate getting IA (Information Assurance) approval to operate. Note that much of this network is fairly static in nature and (depending on DOIM policy and DPW requirements) it may be fairly easy to isolate this network from the remainder of the basewide LAN as discussed below

2.   The BAS will have four distinct types of hardware:

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[*] TP/FT = "twisted-pair/free topology."

a. Individual buildings will have specialized embedded control hardware. These devices are typically highly specialized and should not be considered "IT hardware."

b. Each building will have a CEA-852 "router,"[*] which tunnels ANSI 709.1 traffic from the building controllers (devices on the TP/FT-10 network) over the IP network. While from a control network perspective, "router" is the correct term, in discussions with the DOIM it is very important to *repeatedly* emphasize that these are *not* IP routers; to the IP network they appear as end devices. This device is often referred to as the Building Point Of Connection (BPOC) shown in Figures 1 and 2. The term that is often used in the IT/ DIACAP (Department of Defense Information Assurance Certification and Accreditation Process) world for this device is "IP Platform Interconnect," since it connects a "platform" network to the IP network.

c. A central M&C server, which is a standard personal computer (PC) running a Windows server operating system (OS), specific application software, and will communicate with the CEA-852 routers to provide central management for the UMCS. In most cases, this application software will be dependent on standard server applications such as a database server and/or a web server. Note that the functionality of the M&C server may be spread among several PCs. The M&C server will also support Operator WorkStation (OWS) clients.

d. OWS clients. These are standard PCs, which may or may not be running specific application software. They provide the user interface to the BAS for the system operators.

3. Traffic on the basewide LAN will be of the following types:

a. Most of the traffic on the basewide LAN will be in the form of packets on User Datagram Protocol (UDP) port 1628 and 1629, which are registered with the Internet Assigned Numbers Authority (IANA) for "LonTalk® normal" and "LonTalk® urgent." Most of this traffic will be from CEA-852 routers (the BPOCs) in buildings to the M&C server, although there will be some minor and infrequent traffic between CEA-852 routers.

b. Traffic between the M&C server and client OWSs. While the exact nature of this traffic is vendor-dependent, for almost all vendors, the M&C server will act as a web server and the OWS clients will run a standard browser, possibly with a downloadable Java executable.

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[*] CEA = "Consumer Electronics Association."

c. In some instances, the functionality of the M&C server may be split among several machines. For example one machine may run a database server, another a web server, and a third the actual M&C vendor-specific software. In this case, there will be traffic between the machines, usually utilizing standard ports appropriate for the type of traffic (e.g., database traffic on port 1433). Note that this traffic will be very local to the M&C servers and can easily be isolated from the rest of the LAN.

d. Occasional configuration traffic between the M&C server and the CEA-852 routers. The CEA-852 routers need to know the IP addresses of other CEA-852 routers. They can be manually configured with static IP addresses; however, in most instances, there is a configuration server application that runs on the M&C server and periodically sends updated IP address information to the CEA-852 routers.

4. There are three possible UMCS IP network options as described/specified in UFGS 25 10 10:

a. *Shared LAN with the Basewide IP Network*. In this case, UMCS IP network is the same as the DOIM's basewide IT network and BAS traffic co-exists with other IT application traffic. It is suggested that the BAS be placed on a separate Virtual Local Area Network (VLAN) to improve security. However, the M&C server and OWSs might need to be exposed to the rest of the IT LAN, particularly if a large number or mobile (laptop) OWSs are used.

b. *Co-Located IT Hardware*. In this case, the UMCS IP Network is a physically separate network, but uses spare IT hardware. For example, the UMCS may run on spare network fibers and spare IT closet rack space. In this case, consideration needs to be given to whether there is any connection at the M&C server between the UMCS and the IT LAN, and if so, how to secure that connection.

c. *Completely Independent Network*. The UMCS has no common hardware or space with the IT LAN. Again, consideration needs to be given to whether there is any connection at the M&C server between the BAS and the IT LAN, and if so, how to secure that connection.

Note that normally Army policy dictates that DOIM own/manage *all* IP networks on post. This means that even if an independent network is installed by the contractor, the DOIM will end up owning/managing the network so it is essential that the network be installed in accordance with DOIM requirements.

It is recommended that the installation pursue the first option, where the UMCS uses the basewide IT LAN. This will most likely be the lowest cost option since the contractor will not have to install significant IT hardware or cabling. In addition, there are many IT-specific issues – particularly security – that the DOIM is the logical resource to use on the installation. The only reasons to recommend against this option is if the DOIM places too many restrictions on access to the network, or equipment on the network; however this should not be an issue if UFGS 23 09 23 and UFGS 25 10 10 are strictly followed since they greatly limit the types of equipment that may be used in the buildings.

Assuming that the UMCS network utilizes the basewide LAN, there are several configuration options that should be utilized to simplify network management and provide a basic level of security:

- Network connections between the network drops in the building (BPOCS) and the M&C server should be isolated on a separate VLAN. A VLAN (Virtual LAN) is a networking technology where configuration software operating in IP routers and IP switches allows network connections to be grouped into separate virtual networks that are isolated from each other. This isolation provides a level of security (similar to a firewall) between the UMCS and the rest of the basewide LAN.

- Network connections between the M&C server and client workstations may be secured via several mechanisms. In some cases, fixed, dedicated workstations may be used; in this case, these machines should be on the same VLAN as the rest of the UMCS network. In other cases, the client workstations may be "normal" PCs on the basewide LAN; in this case a firewall should be employed between the M&C server and the basewide LAN to permit traffic from specific client machines only. A third option is to utilize Virtual Private Network (VPN) connections between client machines and the M&C server in conjunction with a firewall; this option permits the greatest flexibility in client workstations while maintaining a high level of security between the UMCS network and the basewide LAN.

Another area of coordination with the DOIM will concern operation of the servers and software control on both servers and clients. The DOIM will

typically have specific policies and procedures in place for the support of server resources on post and should generally be relied on to provide, operate, and maintain the M&C server machine(s). One possible exception would be the vendor-specific M&C software, which may be maintained by the DPW (standard packages, such as a database server and/or web server should probably be maintained by the DOIM). Operating systems on both client and server machines should probably be maintained by the DOIM; however there may be specific requirements for UMCS operation that the DOIM should be aware of.

As mentioned above, several Army policies affect the UMCS network, with the two major ones being DIACAP and Networthiness. While a detailed description of these is outside the scope of this document, some major points are:

- The DIACAP (DOD Information Assurance Certification and Accreditation Process):
  o Applies to any Army information system, regardless of how implemented
  o Is designed for Army wide, centrally deployed systems (i.e., Army Personnel Management System), not an installation-specific UMCS.
  o Is concerned with *Information Assurance* (IA): Continuity/Disaster recovery, Security Design, Physical environment, Personnel, Incident Management, Authentication, etc.
  o Is concerned with operations and policies/procedures as much as with installation
  o May require each UMCS to go through DIACAP process *OR* it *may* be covered under an existing DOIM DIACAP (the latter is *highly* desirable)
  o Requires every UMCS to go through the process independently – an installation may not reference another installation's DIACAP
  o Is very time consuming and expensive
  o Is probably impossible to meet without close coordination with DOIM.

> The key point here is that by far the easiest solution is to get the UMCS covered under an existing DOIM DIACAP for the basewide LAN.

- Networthiness
  - o Is required of any system/component used on an Army LAN.
  - o In some cases, Certificates of Networthiness for identical components may be re-used at a different installation – an installation may reference Networthiness at another installation.

Some other issues to discuss with the DOIM are:

1. If the DOIM discourages connection to the basewide IT network, what are their policies regarding other independent networks? For some installations, other (independent) networks may be prohibited, in which case the UMCS must be on the basewide IT network.

2. What are their requirements for allowing a system to connect to the basewide network? Is DIACAP, Networthiness, or other certification required and if so how should the installation proceed? What restrictions would the DOIM place on the M&C server and client OWSs? The least expensive and time consuming approach is to include the UMCS as an addendum to an existing DIACAP.

3. Access and interconnections (if any) between the UMCS network and the basewide LAN. While the BPOCs do not need a connection to the IT network, there are sound reasons for allowing the OWSs to be on the IT network (which implies that either they are on both the UMCS network and the IT network, or (more likely) that the M&C server is on both LANs):
   a. Use of the IT network for the OWSs allows tremendous flexibility for the location of the OWSs, particularly where the OWS client is a browser with a Java executable. In this case, almost any PC on the IT network becomes a potential OWS.
   b. Use of IT resources from the OWS and/or M&C server, e.g., e-mail, M&C software updates, searching on-line documentation, etc.

4. Inbound access to the UMCS network from off-post. Although not specifically required by the guide specifications, many commercial M&C software packages have the capability of connecting with an OWS over the Internet. If coordinated and implemented with DOIM this may, for example, allow O&M staff to connect from home to perform troubleshooting. This raises obvious security concerns and should not be considered without consultation with the DOIM.

5. Use of wireless networking, Virtual Private Networks (VPNs), or other information technologies to access "hard-to-reach" points on the BAS, for example, a utility substation with metering that is not on the basewide

LAN could conceivably be reached over the Internet with a dedicated VPN or wirelessly.

6. Any firewalls employed to restrict access on the UMCS network, or between the UMCS network and the basewide LAN. Even if the UMCS network is totally independent, the DOIM should be consulted to provide security information regarding the need for firewalls.

Appendix B (p 47) contains a set of "FAQs" that may be useful in answering questions DOIM may have.

The WorkGroup and DOIM may choose to develop a memorandum of understanding (MOU) or similar document describing DOIM expectations and requirements. The MOU might include verbiage to be added to installation-specific UMCS specification, DDC specification, and other BAS-related project specifications (such as in-house contracts). Appendix C (p 52) includes considerations for the creation of a MOU with DOIM.

2.3.3 Define/develop acceptance methodology and checklists

To successfully integrate a building system into a UMCS, the building DDC system must be verified that it is ready for integration. Therefore an acceptance methodology is needed for construction Quality Verification (QV) staff and O&M staff to use in verifying that the building systems have met the specification requirements. The appendices to the guide specifications contain checklists that must be submitted by the Contractor's quality control (QC) representative. While these checklists can be used as a baseline for QV staff they are not a complete acceptance methodology.

Appendix I (p 91) includes a scaled-down draft of a LONWORKS compliance assessment tool, which is a checklist that can be used as one tool in the development of an installation specific acceptance methodology. The actual tool, available at the website listed below, is a spreadsheet that contains comments, hyperlinks, definitions, and examples that are intended to aid the novice. The intent of the checklist is to gage the readiness of building DDC systems for interface with a UMCS, without actually performing the interface, in part because Army installations often procure DDC systems but do not always immediately interface them to a UMCS. The latest version of this checklist is available at the ERDC-CERL BAS Team website at https://eko.usace.army.mil/fa/bas/.

2.3.4 Define training requirements

The UMCS Workgroup should identify training needed to support the
BAS.

O&M staff and system operators are targeted in the UMCS and DDC guide
specs where the installing Contractor is required to provide training. Al-
though the intent of the training requirements in the specifications is to
achieve a degree of proficiency in system operation and maintenance, it
should not be assumed that this training is sufficient. Individual installa-
tions and staff members may have specific training needs. The training re-
quirements in these specifications can be edited to meet specific needs.
Beyond this, it is likely that a degree of formal and specialized training will
be needed to meet the complex demands of microprocessor-based controls
including DDC hardware and software. Possible training options include:

1. *Vendor-Specific DDC Guide Spec Training.* Most construction contracts,
    specifically those that originate at the Corps District level, include contrac-
    tor-provided training requirements. UMCS Workgroup and O&M staff
    should review and help edit the training requirements/specs during the
    design phase.
2. *Vendor-Specific UMCS Guide Spec Training.* The contractor-provided
    training on the UMCS front-end Monitoring and Control (M&C) software
    is extensive and specified in great detail. Still, additional training may be
    warranted depending on the extent that the system operator(s) will be in-
    volved with the operation and management of the UMCS. Individuals that
    will perform system integration functions should receive formal vendor
    training such as that offered at the vendor's formal training facility.
3. *Proponent Sponsored Engineer Corps Training (PROSPECT) Course.*
    "HVAC Control Systems: Design and Quality Verification." (Control No.
    340) provides instruction on LONWORKS® control systems specific to the
    requirements in both the DDC and UMCS guide specs. Although designers
    and Quality Verification staff are targeted, O&M staff would also benefit
    from this course. The course schedule is available from the "USACE Learn-
    ing Center" through URL: http://pdsc.usace.army.mil.
4. *Vendor Training.* Most BAS and DDC system manufacturers offer product
    specific training at the manufacturer's formal training facility. This type of
    training can provide in-depth familiarity with specific products including
    software tools. Training on the Network Configuration Tool (NCT) and on
    the UMCS M&C software would be of value particularly in the case where

the installation has selected a single-vendor NCT and M&C for its basewide BAS/UMCS. Note that both of these pieces of software are specified in the UMCS guide spec.

2.3.5 Develop IDG requirements and in-house LONWORKS® specs

The UMCS Workgroup should update the IDG to accommodate applicable elements of the Implementation Plan. Develop, coordinate, and distribute abbreviated LONWORKS® specs/requirements for use by in-house contracting elements such as Job Order Contract (JOC), Plans and Programs, etc. that can be appended to or used as part of any SOW used to specify BAS-related work performed by in-house elements. Appendix D (p 54) contains sample IDG requirements.

2.4 Identify building integration approach

Although the UMCS may be procured separately from building integration services, the approach used to obtain building integration may greatly impact the procurement of the UMCS. This is particularly true if some type of long-term contracting mechanism will be used for both the initial UMCS procurement and subsequent system integration services. This approach should therefore be identified as early in the process as possible – ideally before the UMCS procurement.

Regardless of the approach, a final goal is to have a UMCS and system integration approach in-place so that as new building level DDC systems are competitively procured they can be integrated with the basewide UMCS.

The following sections discuss integration approaches and contracting mechanisms. Table 1 summarizes the contracting mechanisms that can be used with the different integration approaches.

2.4.1 General system integration approaches

Ideally, the installation will have a specific individual responsible for the integration of all new buildings into the UMCS. This person – the System Integrator (SI) – will be familiar with the system as well as the installations procedures for integration and would therefore be able to efficiently integrate new buildings. While it may be possible to get near this ideal through a long-term contract of some sort, it is not always feasible (in

which case, the integration may have to be performed on a case-by-case basis). In general, the integration approach will be one of the following:

- "In-House" SI
- Long Term Contract for system integration
- Case-by-Case Integration (Using Separate Dedicated Contract)
- Case-by-Case (Using Combined Building Contract and Integration Services).

The following sections describe each of these approaches in detail.

Table 1. Possible contracting mechanisms by integration approach.

| | | System Integration Approach | | | |
		In House	Long-Term Contract	Case-by-Case Separate Contractor	Case-by-Case, Building Contractor
Contracting Mechanism	Local office	Yes	Unlikely[1]	Yes	Unlikely[2]
	ESPC	Yes	No	No	No
	District IDIQ	No	Yes	Yes	No
	Center IDIQ	No	Yes	Yes[3]	No
	District MILCON	No	No[4]	No[4]	Yes

[1]Most installation contracting offices are resistant to this type of contract
[2]The building contract is usually awarded by a Corps district, not the local contracting office
[3]Via MIPR of funds from the district to Huntsville to award
[4]Not as part of the district awarded MILCON job but the district can MIPR funds to be used by one of the other methods.

2.4.1.1 "In-House" system integrator

The installation hires or trains an SI. *This is the preferred/ideal approach.* By having the SI on staff, the installation benefits from maximum flexibility in the use of the SI. The installation does not have to issue task orders or a new contract to get systems integrated and can benefit from ongoing system maintenance. Contracting approaches that fit this category include:

- hiring or training a Government employee
- hiring a contractor through an existing services contract
- establishing a service contract
- obtaining services though another mechanism – such as an Energy Savings Performance Contract (ESPC). Since an ESPC contract is generally for a long period and generally includes more than System Integration service, caution should be exercised with this approach to be sure the installation will be able to effectively work with the ESPC con-

tractor. See section 2.4.2.2 *Energy saving performance contracting (ESPC).*

A key aspect to this approach is that the system integration services are provided at a fixed cost. However, it is important to realize that this fixed cost generally equates to a certain number of man-hours, so the amount of time it takes to integrate a building and the number of buildings that can be integrated will depend on the System Integrator's workload. The purchase of products needed to perform the integration is still dependent on the buildings that are integrated, but this amount is small. If this approach is used, it may be in the best interest of the installation to require that the building DDC system contractor provide the Building Point of Connection (Router) to remove this cost from the SI.

2.4.1.2 Long term contract

With this approach the installation establishes an Indefinite Delivery/Indefinite Quantity (ID/IQ) or similar contract with an SI. This approach allows the installation to obtain integration services from the same entity as each new building system is installed, but generally will require issuing task orders for the integration, which may take additional time. A key aspect of this is to obtain uniform pricing per system for the integration. For example, the DDC guide specification (UFGS 23 09 23) contains standard sequences; the Indefinite Delivery/Indefinite Quantity (IDIQ) contract should specify pricing for integrating these standard systems.

2.4.1.3 Case-by-case integration (using separate dedicated contract)

With this approach, whenever a new building is procured, a separate specification for integration of the building to the UMCS is issued. Maintaining this as a separate contract (rather than including it with the building DDC system specification) reduces the competitive advantage that could be generated by combining the two tasks (see below). Since the original installer of the UMCS system will be most familiar with the system, they may in practice have a small advantage in winning the integration contract, but this is a small task (dollar-wise) compared with the building DDC system. However, anyone familiar with the UMCS system software can perform this integration so proprietary procurement can be avoided. In this approach, tasks other than integration such as system upgrades and maintenance need to be accomplished under a separate con-

tract. As in the combined building and integration contract, if the integration contract ends up being awarded to the building DDC contractor, extra care needs to be taken to ensure that the building contractor does not "cut corners" in the integration.

2.4.1.4 Case-by-case (using combined building contract and integration services)

With this approach, the integration of the building into the UMCS is included in the building specification contract; a single contractor performs both tasks. This can give a competitive advantage to the original UMCS system installer/manufacturer since they will generally be able to integrate the building more inexpensively than could the competition. This can be particularly problematic when the contractor "cuts corners" or provides "value engineering" to reduce the level of openness in the building DDC system since an open building (necessary for integration when the contracts are separate) is typically more costly than a "closed" building. A combined contractor can install and integrate a "closed" building more cheaply than the same contractor could install and integrate an open building. While this is less of a problem with the "case-by-case integration using a separate dedicate contract" approach, it may become problematic when the contracts are combined because this advantage depends not only on the integration, but also on the building DDC system, which can be a large (i.e., costly) project. This is the least desirable approach and is discouraged.

2.4.1.5 Selection of a system integration approach

The system integration approach that the Workgroup decides to pursue will depend on many factors, including the contracting options and funding available to the installation. The "In-House SI" and "Long Term Contract" approaches may (but need not) be funded by the installation. In both cases, the agency issuing the contract to install a building system can likely set aside funds to pay for integration services. For example, if the Corps District awards a Military Construction (MILCON) project for a building DDC system, and the installation has an ID/IQ contract in place for SI services, the District can MIPR funds to the installation to award an integration task on the ID/IQ. Appendix G (p 75) contains an example process (courtesy of Fort Bragg) that describes the steps to be taken to accomplish integration by MIPRing Military Construction, Army (MCA)

funds from Savannah District to Huntsville for award of a task order against an existing Huntsville IDIQ contract. With the two "Case-by-Case" approaches, the agency issuing the contract to install the building system must both fund the integration and include integration requirements in the contract(s) awarded by the issuing agency. The workgroup should identify the approach as part of their basewide BAS planning process.

The open system specified in UFGS 25 10 10 and UFGS 23 09 23 provides some flexibility in contracting Systems Integration and protection against being "locked in" to a specific company or individual. Should the need arise the UMCS and/or the Systems Integrator can be replaced without re-placing the database or any of the building-level systems installed under UFGS 23 09 23. Replacing an SI with another SI with knowledge of the UMCS can be done with minimal effort. Replacing the UMCS, however, requires not only the procurement of new software but the labor to set the new software up to replace the old UMCS, and thus so should be avoided when possible.

If the long-term contract integration option is pursued, three main options should be considered on contract expiration:

1. Keep the current SI (renew the contract). If the installation is satisfied with the SI and the UMCS, this option is preferred; it provides continuity and allows the installation to continue a good relationship with the SI.
2. Issue a contract to a new SI and keep the current UMCS. If the UMCS is satisfactory but the installation is not satisfied with the SI, this option pro-vides an opportunity to work with a different SI while maintaining the in-vestment in (money, time, and effort) already put into the UMCS.
3. Procure a new UMCS and issue a contract to a new SI. If the UMCS is functioning and installation personnel are satisfied with it, this option is discouraged due to the cost of procuring a new UMCS. If the UMCS is un-satisfactory, this option may provide an opportunity to "upgrade" to a UMCS the installation will be satisfied with.

2.4.2 Contracting mechanisms

While evaluating these integration approaches, the Workgroup should also consider the available contracting options. Some options are:

*   Local Contracting Office
*   Energy Saving Performance Contracting (ESPC)

- Corps District ID/IQ Contracts
- Centers of Expertise ID/IQ Contracts.

The following sections describe these approaches in detail.

2.4.2.1 Local contracting office

Depending on the workload and capabilities of the installation Contracting Directorate, the local contracting office may be able to help establish a long-term contract for integration services. Example statements of work (contained in Appendices E and F) will be useful in discussions with the local Contracting office. There is the advantage of working with people in the local area and developing relationships and conveying an understanding of the needs, but set asides and small business rules may restrict options to smaller companies with unknown skills. It is best to provide a very detailed statement of work (SOW) that defines all the specialized requirements and skill sets of the contractor. The Workgroup member(s) should be a part of the evaluation board to ensure the contractor selected is fully qualified and capable.

2.4.2.2 Energy saving performance contracting (ESPC)

ESPC is only one of a large set of performance type contracts where the contractor provides the initial investment and gets paid back from savings. It may be difficult to calculate the savings from building integration into a UMCS, and to qualify for ESPC, a project must show energy savings. If considering using an ESPC for the UMCS installation and operation, it may be best to add the integration services to the statement of work as well. Although ESPCs are widely thought to be the answer to under-funded installations, this funding mechanism does have some disadvantages. Most importantly, finance charges are paid throughout the life of the contract and the installation loses some control over the buildings included in the scope. Changes in building use or configuration that affect the planned savings may cause conflicts with the contract in terms of the shared financial savings. In the worst case, installations may be required to pay contractors "estimated" savings; savings that would have accrued to the contractor if the government had not changed building use or configuration. In some cases, the government has determined that it is advantageous to buy the contract out. If the installation can obtain integration and maintenance services for both the UMCS and the integrated buildings and does

not object to potentially losing a certain amount of direct control over the BAS, this approach may work well.

2.4.2.3 Corps District ID/IQ contracts

Some Corps Districts may have qualified vendors under an ID/IQ contract. They also may have contracting services that will issue the documentation to procure a system integrator for the installation. Each District is unique in this aspect.

2.4.2.4 Centers of Expertise ID/IQ contracts

Most Corps of Engineers Centers of Expertise have a collection of vendors under contract with specialized skills that match up with and support the Center's mission. The Center of Expertise for Utility Monitoring and Control System (UMCS) is Huntsville's Engineering and Support Center. Huntsville has ID/IQ contracts with highly skilled and experienced UMCS vendors. Generally speaking, there are many advantages using the ID/IQ contracting vehicles: pre-selected vendors with focused skills, many years of experience, a long track record of success, no protests, great incentive to partner with and please the customer, and good leverage for problem resolution. The engineers at the Centers are familiar with the new LONWORKS® specifications and can provide design services, technical support during installation, review of submittals, and testing. This work for the installations is funded through fees from the customers. The Centers are reimbursed based on the level of effort requested.

2.4.3 System integrator considerations

It is important to consider the needs of the installation when evaluating potential system integration approaches and System Integrators. For example, the installation may be comfortable performing maintenance on the system and may only need the SI to perform actual integration or they may want the SI to perform maintenance as well. In general, the exact requirements placed on the SI will vary from place to place, but in general, some items to consider are:

1. *Training*. Integrators that work for/represent manufacturers of software for HVAC systems should have formal training on the software. Independent or third-party integrators that use other software (i.e., software not specifically made for HVAC systems, but for control systems in general

such as industrial controls) should have training in the software they are using.

2. *Experience with* LONWORKS® (proven past performance including experience with UFGS 23 09 23 / UFGS 25 10 10 integration projects). This notably includes use of a LonWorks Network Services (LNS) Network Configuration Tool and LNS plug-ins.

3. *Experience with other proprietary protocols and systems that pre-exist on site* should the Workgroup decide that the integration of these systems into the new UMCS is desired.

4. *Familiarity with DOIM and network security requirements.* Prior experience dealing with these requirements would be beneficial, but few integrators may have this experience.

5. *Knowledge of the building-level (UFGS 23 09 23) contractor's requirements* that will impact integration such as:
   a. *Scheduling* – detailed familiarity with these requirements
   b. *Alarm handling* – detailed familiarity with these requirements
   c. *Point Schedules* – how to use them.

2.4.4 Acceptance testing

Testing can be complex and detailed, and can require an experienced field technician or engineer. The UMCS system integrator can be a useful partner in working with UFGS 23 09 23 (or building-level) contractors, by performing submittal reviews, particularly in the case of the Points Schedule drawing and in the case of the control sequences such as alarm handling and scheduling that are highly dependent on ANSI 709.1 and the use of SNVTs. [*] It is important to realize, though, that building-level system acceptance must be accomplished prior to any integration activities so as to avoid potential finger pointing in the event there are problems with the building-level system.

2.4.5 Develop system integration SOW(s)

2.4.5.1 Overview

Based on the selected system integration approach, the Workgroup should develop one or more SOW(s) for UMCS Systems Integrator (SI) support to

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[*] Standard Network Variable Type. A standard format type used to define data for an ANSI 709.1 LONWORKS network

procure services either via long term contract (preferred/ recommended) or on a case-by-case basis (where there are two options as previously described). Alternatively, SI services will be performed in-house, in which case a contract is likely not needed; however, arrangements must be made to define and formalize this SI mechanism.

Appendix E (p 58) and Appendix F (p 70) contain two example Systems Integration SOWs. These SOWs are further described below and should be used with caution and only as applicable to the selected integration approach. Guidance including notes and bracketed options for developing a project specific SOW is contained in the sample SOWs. More recent versions of the SOWs may be available at: https://eko.usace.army.mil/fa/bAS/.

2.4.5.2 UMCS system administrator, technical support representative, and system integrator SOW

The intent of this SOW (Appendix E, p 58) is to get System Integrator on staff who will establish and create a UMCS in accordance with the requirements and intent of UFGS 25 10 10. The SOW defines scope and requirements to develop and document a System Integration Methodology, develop and document a System Operation Methodology, manage and operate the UMCS according to the Operation Methodology, and to provide DPW-embedded maintenance support. This SOW contains a placeholder where the '*UMCS DDC Integration SOW*', described below, can be included.

2.4.5.3 UMCS DDC integration SOW

This SOW (Appendix F, p 70) defines scope and requirements to integrate LNS-based LonWorks building control system(s) into an LNS-based LonWorks UMCS.

2.5 Document the implementation plan

The UMCS Workgroup should document the target basewide BAS and describe how to obtain it. The plan should include the results of the previous steps and guide the execution of the procurement and expansion of the UMCS. This plan should be considered a living document and should be updated periodically as lessons are learned from its execution. It should be as complete as possible and should define BAS goals, features, functions,

requirements, needed support, integration approach, contracting methodology, and a path forward.

Once the implementation plan is documented it should be reviewed and coordinated with the Workgroup as well as any other individuals or offices/agencies who will be affected by it. Appendix H (p 78) contains a sample plan. Some topics to include in the plan are:

1. *UMCS Workgroup.* Provide a list of members.
2. *Purpose/Problem.* Describe the current BAS situation including a description of the existing systems and problems that need to be addressed/overcome.
3. *Goals and Benefits.* Describe the goal(s) and benefits. Focus on the big picture functions and capabilities of the system.
4. *BAS Description/Characteristics.* The plan should describe characteristics, features, and functions of the proposed BAS in more detail than that in the Goals/Benefits section. This might, for example, address/include:
   a. The need for a computer operator workstation located in the Energy Manager's office, one in each Work Leader's office, one in each shop common area
   b. The capability to set up and change schedules from each operator workstation (OWS)
   c. Other energy management functions such as monitoring and subsequent reports for specific systems or subsystems
   d. The need for certain types of alarms and for alarms to be directed to specific shops/individuals
   e. Building-level DDC system functions/features. UFGS 23 09 23 contains specific detailed sequences of operation; if the installation desires "standard deviations" from those sequences (e.g., pneumatic actuators, tighter sensor tolerances, etc.), then they should be documented here and/or in the installation design guide (IDG).
   f. Training and certain types of technical assistance.
5. *Support Structure.* The plan should define support requirements and a proposed support structure. This includes an internal support structure along with internal/external technical and contracting support. The support structure should include the designation of responsible parties for all aspects related to ongoing support of the BAS. It should also point out the need for coordination with specific in-house entities such as DOIM and Contracting office(s):
   a. UMCS Workgroup

b. UMCS System Integrator (likely a Contractor, but possibly in-house staff)
c. DOIM Liaison
d. Computer System Administrator (Attends to computer issues: Operating system upgrades, users, etc.)
e. UMCS System Administrator
f. Laptop Manager (hardware/software management)
g. UMCS Operator(s)
h. DDC Specialists (hardware/software experts)
i. Building Acceptance point of contact (POC)
j. In-house contracting mechanisms/entities.
    In regard to the in-house contracting mechanisms/entities, the plan should identify and list each in-house contracting mechanism that might be involved in the procurement of BAS elements (such as JOCs, Plans and Programs, etc.), regardless of who procures them. Open, non-proprietary, interoperable systems must include at least minimal specifications to ensure compatibility of these systems with the LONWORKS® UMCS. Coordination of these requirements with the in-house contracting entities is necessary to help ensure that all procured systems meet these requirements.

6. *Path Forward*. The plan should describe subsequent steps and expectations.

2.6 Execute UMCS procurement

Once the implementation plan is complete, the Workgroup can proceed with the procurement of a UMCS as described in the plan.

3   Conclusion

This work has identified and documented an overall strategy for site-specific implementation of an Open basewide BAS based on LONWORKS® technology and American National Standards Institute (ANSI) communications standard 709.1 where the BAS consists of a basewide Utility Monitoring and Control System (UMCS) that is interoperable with multi-vendor LONWORKS® direct digital control (DDC) systems.

While no two Army installations are identical in their BAS needs and requirements, the overall implementation process is much the same across installations. It is strongly recommended that each Army installation develop and document a BAS implementation plan and maintain this plan as a living document in coordination with the installation's IDG. It is beneficial for the installation to create a workgroup minimally consisting of members from the DPW including the Energy Manager, maintenance shop(s), and Engineering staff, DOIM, and the Corps of Engineers District and Area Offices. The workgroup should create plan and guide the implementation where key elements of the implementation include:

- Identify a mechanism and approach though which the installation can obtain system integration services where third party DDC systems are integrated with the UMCS front-end.
- Coordinate and work with the DOIM on information assurance and security requirements. In particular, The UMCS will need a DIACAP (certification) and this is best accomplished as an addendum to (under) an existing DIACAP.
- Make sure Points Schedule drawings are developed for and used on all DDC projects.
- Take time to perform DDC system quality verification and acceptance activities especially for the first few projects so as to help ensure that your DDC Contractors understand the project requirements.

While BAS technology can be complex, successful implementation is primarily a matter of familiarity with and exposure to the specifications and requirements.

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Acronyms and Abbreviations

Term	Spellout
A/E	architect/engineer
AFB	Air Force Base
ANSI	American National Standards Institute
ASC	application specific controller
ASHRAE	American Society of Heating, Refrigerating, and Air-Conditioning Engineers
BAS	Building Automation System
BPOC	Building Point of Connection
BRAC	Base Realignment and Closure
CEA	Consumer Electronics Association (CEA)
CEERD	U.S. Army Corps of Engineers, Engineer Research and Development Center
CERL	Construction Engineering Research Laboratory
CO	Contracting Officer
COE	Corps of Engineers
COR	Contracting Officer's representative
COTR	Contracting Officer's Technical Representative
CSMA/CD	carrier sense multiple access with collision detection
DDC	direct digital control
DHCP	Dynamic Host Configuration Protocol
DIACAP	Department of Defense Information Assurance Certification and Accreditation Process
DITSCAP	DOD Information Technology Security Certification and Accreditation Process
DOD	Department of Defense
DOIM	Directorate of Information Management
DPW	Directorate of Public Works
DSN	Domain, Subset, Node
DX	Directory of Expertise
EBI	Enterprise Buildings Integrator
ECB	Engineering and Construction Bulletin
ECIP	Energy Conservation Investment Program
EIA	Electronic Industries Alliance
EMCS	Energy Monitoring and Control System
ERDC	Engineer Research and Development Center
ESPC	Energy Savings Performance Contract
FAQ	frequently asked questions (FAQ)
FMD	Facilities Maintenance Division
GPPC	General Purpose Programmable Controller
GUI	graphical user interface
HNC	Huntsville Center, Alabama (HNC)

Term	Spellout
HQ	headquarters
HQUSACE	Headquarters, U.S. Army Corps of Engineers
HTML	hypertext markup language
HTTP	hypertext transfer protocol
HVAC	heating, ventilating, and air-conditioning
I/O	input/output
IA	Information Assurance
IANA	Internet Assigned Numbers Authority
IATO	Interim Authority To Operate
ID/IQ	indefinite delivery indefinite quantity
IDC	Indefinite Delivery Contract
IDG	Installation Design Guide
IDIQ	Indefinite Delivery/Indefinite Quantity
IM	instant messaging
IMCOM	Installation Management Command
IMO	Information Management Office
IP	Internet protocol
IT	Information Technology
JCI	Johnson Controls, Inc.
JOC	Job Order Contract
LAN	Local Area Network
LCS	LONWORKS Control Station
LDP	local display panel
LEED	Leadership in Energy and Environmental Design
LNS	LonWorks Network Services
M&C	monitoring and control
MCA	Military Construction, Army
MCX	Mandatory Center of Expertise
MILCON	Military Construction
MIPR	Military Interdepartmental Purchase Request
MOU	memorandum of understanding
NAC	Network Access Control
NACLC	National Agency Check with Local Agency and Credit Check
NCT	Network Configuration Tool
NTP	Notice To Proceed
O&M	operations and maintenance
OI	Operator interface
OMA	Operations and Maintenance, Army
OMB	Office of Management and Budget
OMD	Operations Maintenance Division
OS	operating system

Term	Spellout
OSI	Open Systems Interconnection
OWS	Operator Work Station
P&P	Plans and Programs
PC	personal computer
PDA	personal digital assistant
PDF	Portable Document Format
POC	point of contact
PROSPECT	Proponent Sponsored Engineer Corps Training
PVT	Performance Verification Test
QC	quality control
QV	Quality Verification
RFP	request for proposal
ROM	read only memory
SAS	Savannah District
SCADA	Supervisory Control And Data Acquisition
SI	System Integrator
SIM	System Integration Methodology
SNMP	Simple Network Management Protocol
SNVT	Standard Network Variable Type
SOW	statement of work
SQL	structured query language
SSBI	Single Scope Background Investigation
TCP	Transmission Control Protocol
TP/FT	twisted-pair/free topology
TR	Technical Report
TSR	technical service representative
UDP	User Datagram Protocol
UESC	Utility Energy Services Contract
UFGS	Unified Facilities Guide Specification (UFGS)
UMCS	Utility Monitoring and Control System
URL	Universal Resource Locator
USACE	U.S. Army Corps of Engineers
VLAN	Virtual Local Area Network
VPN	Virtual Private Network
XIF	eXternal Interface File
XML	Extensible Markup Language

Appendix A: Control Systems Assessment Statement of Work

The following is a sample statement of work (contract) (SOW) used for the implementation of the guidelines in this report at several installations. For use at a single installation, this SOW must be tailored to refer to installation specific requirements and to refer to only one installation.

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STATEMENT OF WORK

ARCHITECT-ENGINEER SERVICES FOR

IMCOM BUILDING AUTOMATION SYSTEM IMPLEMENTATION PLANS

FOR FORT BRAGG, NORTH CAROLINA, FORT LEE, VIRGINIA,

FORT BLISS, TEXAS, AND FORT HOOD TEXAS

</div>

1. REFERENCE. Indefinite Delivery Contract (IDC). This task order will be issued under IDC W912HN-05-D-0017.

2. OVERVIEW. This work is in association with a joint effort among ERDC-CERL, Huntsville Engineering and Support Center, and Savannah District funded by Installation Management Command (IMCOM) to define a methodology for the development of a basewide open BAS plan based on LONWORKS® technology and ANSI standard 709.1 as specified in UFGS 25 10 10 and 23 09 23 where the BAS consists of a basewide UMCS that is interoperable with multi-vendor LONWORKS® DDC systems.

3. DESCRIPTION OF WORK. This SOW covers all services to perform site visits to four installations: Fort Bragg, North Carolina; Fort Bliss, Texas; Fort Lee, Virginia; and Fort Hood Texas; and to prepare resulting reports based on the site visits. This will include pre-site visit planning and coordination with all team members, LONWORKS® site assessment, on-site coordination assistance/participation, development of site-specific Implementation Plan verbiage, tables, and data, in an Assessment Report. The objective is for the architect/engineer (A/E) to perform a site-specific assessment of LONWORKS® BASs and BAS components to determine if and to what extent the installations' BASs are in compliance with the require-

ments defined in UFGS 25 10 10 and UFGS 23 09 23. The A/E shall provide recommendations on how the installation can proceed to obtain a basewide UMCS in accordance with UFGS 25 10 10 and 23 09 23 including an assessment of local contractors' capability to support UFGS 25 10 10 and 23 09 23 where the goal is to assist each installation prepare for and achieve state of the art, maintainable, operable, and cost effective basewide BAS. For the purposes of this SOW, a BAS is defined as a group of DDC systems interconnected via a communications network (such as IP) with a front-end/UMCS and a standalone DDC system is defined as one that is not connected to a front-end/UMCS.

4. __REQUIRED A/E SERVICES.__ The A/E shall perform the services indicated in the Statement of Work. These services will be provided in three distinct phases:

- Pre-site visit planning
- Pre-site visit telephone calls to site staff
- Site visits
- Assessment Reports.

4.1. Pre-site visit activities.

a. Participate in a conference call with SAS, HNC, ERDC-CERL and POC(s) from each site to review the technical requirements of this SOW. The purpose will be to go over the thrust of the effort, to identify all initial points of contact, and to solidify the details of the site visit and the reports. Anticipated level of effort: 0.5 days.

For each installation, the following shall be accomplished:

b. Contact the Government supplied site POC to schedule a site assessment visit with appropriate personnel to assist in performing the tasks described in the SOW. Personnel may include; the Energy Manager, DPW Chief of O&M Division, DPW Chief, O&M Production Control, DPW Shop Foreman, DPW Work Leader, Engineering Services Branch Chief, and DPW HVAC/Controls staff, DPW A-76 Contractor (IAP) HVAC/Controls staff. Notify the Government of scheduled site visit(s). For Fort Hood related work the A/E need only speak and meet with Mr. Dick Strohl. Anticipated level of effort: 0.5 days per site.

c. Obtain as much advance information listed in exhibit A as is possible via telephone calls in advance of site visits. For Fort Hood, the A/E need not execute the items in Exhibit A. Anticipated level of effort: 3 days per site.

4.2. Site visits. For each the installation, the following shall be accomplished:

Perform site visits to identify and quantify the installation's BASs. The intent is to get a working sense from a long term planning perspective of the state of the installation's BASs and to obtain lessons learned. The information in Exhibit A shall be obtained. For Fort Hood, the A/E need only update the report: SITE SURVEY AND DATA COLLECTION UTILITY MONITORING AND CONTROL SYSTEM (UMCS) MASTER PLAN FORT HOOD, TEXAS including; Chapter 1. General Description, Chapter 2.2 Review of UMCS Currently Installed at Fort Hood, and Chapter 3. Buildings For Future UMCS Master Plan. The Fort Hood work shall include new LONWORKS® control system additions to the existing SITE SURVEY. Anticipated level of effort: 5 days per site.

4.3. Assessment Report.

a. For each installation, after the site visit, the A/E shall provide a finished Assessment Report documenting the site assessment and providing all information described above including names of individuals that the A/E spoke and met with. The assessment shall include the recommendations on how the installation could proceed to obtain a basewide UMCS in accordance with UFGS 25 10 10 and 23 09 23, including the assessment of local contractors' capability to support UFGS 25 10 10 and 23 09 23. In the case of Fort Hood, the A/E need only update the SITE SURVEY report. Anticipated level of effort: 2 days per site.

b. For each installation, the A/E shall schedule a conference call to present and discuss the Assessment Report to ERDC-CERL, Savannah District, and Huntsville Engineering and Support Center. Both parties will discuss the issues and, if necessary, attempt to resolve unsettled issues that may arise. Anticipated level of effort: 0.5 days per site.

4.4. Notes and Discussions. The A/E shall take notes and prepare minutes for all meetings and conferences attended during the project. Minutes

shall be signed by the project manager and furnished to the Savannah District project engineer within 7 calendar days after the meeting/conference for concurrence and distribution. The A/E shall provide a written record of all significant discussions and telephone conversations that the firm's representatives participate in, on matters relative to the project. Records will be provided within 7 calendar days of the conversations. Anticipated level of effort: included in above tasks.

5. **SUBMITTALS AND PERFORMANCE SCHEDULE**.

5.1 All deliverables will be provided electronically to the Savannah District project engineer. Deliverables include:
- Notes and minutes of all conferences – included in Assessment Report.
- Record of significant discussions and conversations – included in Assessment Report.
- Assessment Report and update of the Fort Hood SITE SURVEY report – within 7 calendar days of completion of the site visit.

5.2. Performance Periods and Submission Schedules. The performance periods and submission schedules for each item are indicated below. All activities must be completed by 30 July 2007.

Item	Due after Notice To Proceed (NTP) (calendar days)
a. Notice to Proceed	---
b. Conference call (A/E, CERL, SAS, HNC)	8
c. Site visit 1 complete	As mutually agreed
d. Submit Site 1 Assessment Report	14 days after item c.
e. Site 1 conference call (A/E, CERL, SAS, HNC)	7 days after item d.
f. Site visit 2 complete	As mutually agreed
g. Submit Site 2 Assessment Report	14 days after item f.
h. Site 2 conference call	7 days after item g.
i. Site visit 3 complete	As mutually agreed
j. Submit Site 3 Assessment	14 days after item i.
k. 3 conference call	7 days after item j.

6. **AUTHORIZED CHANGES.** The A/E shall accept instructions only from the Contracting Officer or his duly appointed representative. Coordination of routine technical matters with Corps of Engineers personnel will

be accomplished through the project engineer, Lucie Hughes, CESAS-EN-EP. Direct requests from other agencies should be forwarded to the Project Engineer for consideration.

7. <u>EXHIBITS</u>.

A. Installation Assessment Information

EXHIBIT A

Installation Assessment Information

BAS System List: List of LONWORKS® and non- LONWORKS® BASs, both existing and under construction. Where available provide diagrams in Adobe® Portable Document Format (PDF) or other electronic format
Total number of buildings connected to a BAS, as a total number and as an estimated percentage of the installation.
BAS System details: For each BAS on the BAS System List provide the following information:

Operator interface (OI) system name and manufacturer. Provide version number if available and applicable particularly where it might be of interest as part of a basewide systems integration plan. For example, if the OI is widely used or applied or is LNS compatible. Number of buildings connected to the BAS, as a total number and as an estimated percentage of the installation or other indication of the system size at contractor's discretion

- Functions and Utilization. Provide a summary of functions that the BASs perform (alarms, scheduling, trending, etc.) particularly those functions of interest and value to the DPW. Provide an indication of the degree and type of utilization of the BASs by the DPW and others.
- Unusual types of equipment monitored or controlled such as lighting systems, energy-monitoring-only systems, access control systems, etc. where the intent is obtain an awareness of any special needs or requirements that the installation might have beyond ordinary HVAC control.
- For each building connected to the BAS provide:
  ◦ Building numbers, building group, or area. The intent, within time and resource constraints, is to obtain as much detail as is reasonably available.

- ◦ Product (manufacturer) name for DDC controls contained within/under the BASs. The intent is to obtain insight into the variety and types of DDC hardware at the installation. As part of this, of interest is the relative quantities of ASCs versus General Purpose Programmable Controllers (GPPCs). Interaction with a knowledgeable individual in one of the DPW shops can facilitate this effort.
  - ◦ Installing controls contractor name. (Also see related requirement later in the Exhibit).
- ▪ For LONWORKS® BASs, provide an assessment of each ones compliance with UFGS 25 10 10 and answer the following questions:
  - ◦ What media type was used?
  - ◦ Are UFGS 25 10 10 compliant CEA 709.1 to IP (CEA 852) routers used?
  - ◦ Are gateways (such as NAE's, JACE's, or other similar products) used? If yes, list gateways including product name.
  - ◦ Are alarms implemented in accordance with UFGS 25 10 10 and in compatible accordance with UFGS 23 09 23?
  - ◦ Is (occupancy) scheduling accomplished in compatible accordance with UFGS 23 09 23?
  - ◦ Were licensed copies of an NCT submitted? How many copies? Where are they?
b. What DDC and BAS preference(s) does the installation have such as a particular brand or type of control (such as application specific controller [ASC] versus General Purpose Programmable Controller [GPPC]). Any/all insights are useful.
c. Description of how the various BASs are integrated such as; Are there multiple front-ends, are any on the basewide LAN, are there gateways at the building level, are different manufacturers systems integrated together, are there BASs that are contain control networks at the building level, but are not interfaced to an OWS, are any BASs configured for dial-up-only access, etc.
d. Summary of BASs and buildings that are based on LONWORKS® technology.
e. Summary of and UFGS 25 10 10 compatible front-ends that have a software gateway to the existing BAS. (e.g., a Johnson Controls, Inc. (JCI) Network Application Engine (NAE) with an NIE to an existing Metasys BAS)
f. For LONWORKS® building-level systems (that may or may not be part of a BAS, i.e., these can be "standalone" systems), identify compliance with UFGS 23 09 23 for a representative sample of not less than three UFGS 23 09 23 systems, in each case installed by different contractor. Provide the following:
   - ▪ Assessment of submittals:

- ◦ Were Points Schedule drawing(s) submitted? Obtain and submit copies of the Points Schedules. Provide an opinion as to whether the Points Schedules meet the intent and requirements of UFGS 23 09 23.
- ◦ Was an LNS database submitted?
- ◦ Were eXternal Interface File (XIF) files submitted?
- ◦ Were LNS plug-ins submitted? Are LNS plug-ins available (from the manufacturer) for the installed devices?
- ◦ If programmable controllers were used was the programming software submitted? Was the application program submitted?
- ▪ Are the building systems in accordance with the UFGS 23 09 23 LONWORKS® requirements? Provide an overall answer to this question as well as specific answers to the following:
  - ◦ Was the "scheduling sequence" accomplished in accordance with UFGS 23 09 23
  - ◦ Are alarms implemented in accordance with UFGS 23 09 23?
  - ◦ Was a critical alarm handler provided?
  - ◦ Is there a System Scheduler?
  - ◦ Are all devices connected to a TP/FT-10 building control network?
- ▪ What O&M tools (such as an NCT) were provided or are otherwise available? Do the tools meet UFGS 23 09 23 and 25 10 10 requirements? For TP/FT-10 networks are there network interface jacks available as specified and are there dongles available for workstation (laptop) connection? Are there software packages or tools other than an NCT?
- ▪ Perform a network analysis of one building's (or more if time permits) TP/FT-10 network and compare the results to the requirements of UFGS 23 09 23 and the Points Schedule.
- g. Identify and list local vendors/contractors (name, phone, e-mail, website) who do work at the installation.
  - ▪ If available, provide an indication of the extent/magnitude of their work experience at the installation such as how many jobs (such as many, few, one), job size (numerous systems, one or two buildings), and approximately how long have they been doing work at the installation.
  - ▪ Provide an assessment of their capability to install and support LONWORKS® in accordance with UFGS 23 09 23 and 25 10 10, particularly LNS.
  - ▪ What UMCS/DDC brands/product lines does the contractor support? Are the products LNS compatible?
  - ▪ How much experience does each Contractor appear to have with UFGS 23 09 23/25 10 10 systems?
  - ▪ Assess Contractor's potential/capabilities to implement UFGS 23 09 23 scheduling and alarm sequences.

- What Contractor preferences does the installation have? Are any contractors on a non-compliance or "problem" list? If yes, indicate why if the reason is known and publicly available non-sensitive information.

Appendix B: DOIM Frequently Asked Questions (FAQs)

1. What is ANSI 709.1?

The "Control Network Protocol Specification" ANSI 709.1 is an ANSI standard communications protocol (including Open Systems Interconnection [OSI] layers 1 through 6, originally developed by the Echelon Corporation (Echelon refers to it as "LonTalk®") and widely used for data communication between devices designed for monitoring and control of building automation systems.

2. What bandwidth requirement and traffic profile does it have?

The average bandwidth requirements are very low, with occasional (still quite modest) peaks. Almost all traffic will be between a single building point of connection (BPOC) and a master front end monitoring and control (M&C) computer, and it is meaningful to discuss network bandwidth requirements at two points:

- Inside the building, traffic is on a dedicated carrier sense multiple access with collision detection (CSMA/CD) network (not part of the IP network) operating at 78 kbps. This inherently limits the bandwidth on the IP network side.
- The greatest bandwidth requirement will be at the central M&C server, where the average requirement can be estimated based on two factors:
  - *Communications from the buildings.* While this traffic increases with the number of buildings each building contributes only a small amount to the bandwidth usage.
  - *Communication between the software server and clients.* The bandwidth usage will depend on the software used and the number of workstations. This communication is more bandwidth intensive than communications with the building systems, but depends on the number of OWSs, not the number of buildings. The small amount of data exchanged (say 20 pieces of data for a typical "refresh" between a client and the server) results in a low bandwidth utilization.

Note that, by the very nature of building automation systems, most data packets will be very small; the data portion of the IP packet will generally be on the order of 64 bytes or less.

3. Does it use standard protocols, including TCP, IP, DHCP, and SNMP?*

Yes. ANSI 709.1 is a standard protocol including OSI layers 1 through 6; however it can run on an IP network via a tunneling protocol, CEA-852. As far as the IP network is concerned, the basewide network will consist of these 852 "routers," one (or two if redundant servers are installed) central monitoring and control (M&C) computers, and additional computers acting as clients to the central M&C computer. Specific installations may increase the number of server computers. For example, some vendors use Microsoft Structured Query Language (MS-SQL) for an underlying database and/or use a web server for client access and these components may be distributed among multiple servers; these installations will have additional server – server traffic on standard ports. These devices will all use TCP/IP and (optionally, at the DOIM's discretion) Dynamic Host Configuration Protocol (DHCP).

Many (if not all) client – server communication will use HTTP on port 80.

4. Will there be unmanaged web servers on the network?

No. The BAS specified under UFGS 23 09 23 and UFGS 25 10 10 does not use HTML, XML, Web Services, or http to communicate among devices. Depending on the vendor selected under the UMCS contract according to the UMCS specification, the front-end M&C server will probably use a *managed* web server to support operator workstations. However, this will be a single (or perhaps a small number of co-located) machines that can be located in a secure area. If this is a concern, the DOIM representative on the BAS Working Group should help to define additional requirements and/or restrictions on the UMCS Contractor to ensure that any web servers will meet DOIM requirements.

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* TCP =- "Transmission Control Protocol"; IP = "Internet Protocol"; DHCP = "Dynamic Host Configuration Protocol"; and SNMP = "Simple Network Management Protocol."

5. What other protocols are used?

The normal sharing of data packets between BPOCs located at the buildings and the M&C server is tunneled via CEA-852 on IANA-approved ports UDP 1628 and UDP 1629.

6. Does it use broadcasts?

The CEA-852 routers do not use broadcasts—they tunnel ANSI 709 packets as point-to-point packets to other CEA-852 routers. The M&C server and client computers will run a standard operating system that may use broadcasts (but this is not specific to the control system and DOIM is used to dealing with such operating systems). There may be limited numbers of broadcasts during the initial configuration of the CEA-852 routers; however it is not necessary that these broadcasts be forwarded by IP routers.

7. What are the IT connectivity requirements?

Each building will require a single network drop and (preferably) static IP address for each of CEA-852 router. For large buildings, it is possible that two or more CEA-852 routers will be used, in which case more network drops and IP addresses will be required. Point-to-point links will be implemented between these 852 routers and also between these 852 routers and a single (duplicate if redundant hardware is installed) front-end monitoring and control (M&C) server computer. Because this network configuration is fairly static, a VLAN should be constructed to isolate all the 852 routers and the M&C server from the rest of the IP network. However, there will be other client computers connected to the front end M&C server; these machines may be on the same VLAN as the 852 routers, or they may be on a more general basewide IT VLAN, in which case the M&C server would need to exist on both VLANs. As an additional security enhancement, VPNs may be used to connect workstation client machines to the M&C server.

8. What existing IT infrastructure components beyond the network itself will be affected?

In many cases, there will be a need for a database server and/or a web server. Purchase, installation, operation, and maintenance of these machines may be included in an MOU between DOIM and the DPW.

9.   What new network infrastructure components are required?

Buildings will need a connection to the basewide IP backbone. For buildings where this already exists, no new components are required beyond a network drop and an IP address. Since these devices require no connectivity beyond the M&C server, static private addresses are preferable.

10.   How are the network components secured?

Ideally, with DOIM permission, the CEA-852 routers will be secured in the same network closets as the standard DOIM IP hardware and isolated on a dedicated VLAN. The M&C server and other client workstations will be secured using whatever means the DOIM uses for standard office PCs. (Note that the use/capabilities of these computers could actually be more restricted than for a standard office computer. For example, these machines should not require access to the Internet so it would be possible to deny them this access. Additional requirements may be placed on these machines; the only operational requirements are that the M&C server be able to communicate with the BPOCs and with the workstation clients.) No specific security requirements are necessary for the low-level control hardware inside the buildings.

11.   Can the network components be infected by a virus?

No. The network components in the building are low-level embedded processors, running very specific control algorithms on non-Windows operating systems and are not subject to attack by viruses, trojans, or worms designed to attack general purpose PCs and network hardware. Similarly, the 852 routers are designed for a specific task – the routing of ANSI 709 packets. The fact that they are not IP routers, not general purpose computers, and are not servers makes them extremely secure against outside attack.

12.   Can network components be hijacked to infiltrate a network?

No. The low-level controllers are on a dedicated (non-IP) network that does not have connectivity outside the building. In addition, the preferred configuration places the UMCS IP network on a protected VLAN and not exposed to outside attack. Any possible attack against them presupposes that the basewide IP network has already been compromised. Even in the

unlikely event of a successful attack against the building control network, the 852 router does not support standard/common clients – its usefulness as a platform to attack the rest of the network is practically non-existent. (Obviously the IP network – routers, switches, and cable drops – needs to be protected by standard DOIM security measures.) Finally, in the event of a successful attack against the BAS, the compromised hardware is still on an isolated VLAN. The M&C server PC and OWSs will be protected as any standard PCs and DOIM input is required to determine the best approach to protecting these machines.

13.   Will it require any non-standard ports be opened?

Almost certainly not. The communication between 852 routers and each other and the M&C server uses UDP and TCP ports 1628 and 1629, which are registered with IANA for "LonTalk normal" and "LonTalk urgent." Communication between the M&C server and client workstations will almost certainly be via HTTP on port 80; but it is possible that some vendor will not use HTTP on port 80 and will require some non-standard port.

Appendix C: DOIM MOU

Considerations for the DOIM MOU:

- The DOIM POC is: _____.
- The BAS Workgroup POC is: _____.
- DOIM will review any contract/procurement package that includes IP equipment.
- DOIM has ownership of UMCS server(s) while DPW owns the application.
- DOM will provide DPW and assigned/designated Contractor(s) with full access to the Monitoring and Control (M&C) application software in order to perform certain activities such as LNS database creation/merging, graphic development, point definition, etc.
- DOIM will maintain the OS and perform daily backups.
- The Workgroup / DPW will notify DOIM of any unscheduled IP-related work.
- Server(s) and their location will be pre-approved by DOIM.
- Un-managed servers are not permitted.
- BPOCs shall be located in DOIM communications closets or other DOIM approved spaces.
- BPOCs shall be tested for [_____].
- DOIM will provide static IP addresses.
- Server and workstation Operating System software shall be [Windows XP].
- Office automation system software shall be [MS Office Professional Version x or later].
- E-mail software shall be [_____].
- No instant messaging (IM) software shall be permitted on any computer.
- M&C Server software will consist of: (for example) database server [_____], web server [_____], etc.
- Server hardware and software will be provided by [_____].
- Server maintenance will be provided by [_____].
- Client workstation maintenance will be provided by [_____].
- DOIM will provide DPW with Local administrator access/rights to the Application programs (need to list these).

- Workstation administrator requirements include: [DOIM will list/describe System Administrator training/certification requirements that may be needed by the DPW or DPW-hired-contractor(s)]
- etc.

Appendix D: Installation Design Guide Draft Verbiage

Short Version

Digital controls shall be based on LONWORKS® Technology designed and installed in accordance with UFGS 23 09 23, which is based on ANSI/CEA 709, Energy Information Administration (EIA)-852, and the LonMark Interoperability Guidelines in support of base-wide multi-vendor interoperability. Gateways (protocol translators) shall be avoided, but may be provided on an exception basis only as specified in UFGS 23 09 23. BAS technologies that lead to proprietary sole-source procurement for system expansions are not acceptable. (An exception to UFGS 23 09 23 is that general purpose programmable controllers [GPPC] shall not be used. Instead, only application specific controllers [ASC] are permitted. Where an application specific controller is deemed unsuitable by the contractor due to the complexity of the application, the contractor shall obtain Contracting Officer [or CO Representative] approval for use of a programmable controller.) Contractor's are encouraged to propose an alternate (less complex) control sequence that will result in the use of an application specific controller (ASC) in lieu of a programmable controller. Control system installation shall be coordinated through the DPW with the Fort [_____] UMCS System Integrator culminating, as specified in UFGS 23 09 23, in the submission of an LNS database for the project and an LNS plug-in for each installed application specific [and general purpose programmable] controller/device.

Detailed Version: (Courtesy of Fort Hood, TX)

LONWORKS® is the overall open systems communication technology for building automation systems. LONWORKS® is further described by "LonMark International," an industry organization established to support LONWORKS® technology (http://www.lonmark.org). The term may include reference to any/all of the: protocol, network management, and interoperability guidelines where the technology is based on the Energy Information Administration (ANSI/EIA) 709.1B protocol and employs interoper-

able devices along with the capability to openly manage these devices (via multiple vendors) using a network configuration (or service) tool.

All new and renovation control projects, where the controls are to be interfaced to the Utility Monitoring Control System (UMCS), shall be coordinated with the Fort Hood UMCS "System Integrator" through the DPW Energy Branch. The UMCS interface design shall be in accordance with Unified Facility Guide Specification 25 10 10 (Utility Monitoring Control System – formerly UFGS 13801). In cases where 25 10 10 may not be used, the project design must minimally include a "Points Schedule" that lists:

- domain/subnet numbers (obtained from the UMCS System Integrator) for the installed controls:
- all points/values to be displayed/monitored at the UMCS
- points that must have override capability (such as setpoints, equipment on/off settings)
- alarm conditions/setpoints (if applicable) along with names, e-mail addresses, and/or pager numbers of individuals to be contacted (by the UMCS) in the event of an alarm.

Unified Facility Guide Specification 23 09 23 (Direct Digital Control for HVAC and other Local Building Systems – formerly UFGS 15951) addresses specifies system requirements for Direct Digital Controls (DDC) using LONWORKS® that are applicable to Fort Hood. Fundamental 23 09 23 requirements, plus Fort Hood specific requirements (as indicated by the wording "At Fort Hood …") include:

1. The control system shall be an open implementation of LONWORKS® technology using ANSI/EIA 709.1 as the communications protocol and using LonMark Standard Network Variable Types as defined in LonMark Standard Network Variable Type (SNVT) Master List for communication over the network;
2. All DDC hardware shall be connected to a TP/FT-10 ANSI/EIA 709.3 control network and communicate over the control network via ANSI/EIA 709.1B exclusively.
3. LONWORKS® Network Services (LNS) shall be used for all network management including addressing and binding of network variables. A copy of the LNS database shall be submitted to the project site as specified.
4. The hardware shall perform the control sequences as specified and shown to provide control of the equipment as specified and shown.

5. LonMark certified control hardware (devices) shall be used when a device that meets the control sequence is available. Certified devices are listed at http://www.lonmark.org/products/. At Fort Hood, if minor deviations from the specified control sequence would permit the use of a Certified device (when one is otherwise not available), the contractor is encouraged to submit the Certified device along with a description of the deviation(s). Non-certified devices are permissible as long as they otherwise adhere to the specified LONWORKS® requirements.

6. At Fort Hood, application specific control (ASC) hardware is preferred over programmable controllers. If minor deviations from the specified control sequence would permit use of an ASC (when a programmable controller would otherwise be required), the contractor is encouraged to submit the ASC along with a description of the deviation(s).

7. LNS plug-ins shall be provided with all control hardware. Devices without LNS plug-ins shall be used on an exception basis only and require Government approval. A partial list of control hardware with LNS plug-ins is available through URL:
http://www.echelon.com/products/networktools/plugin/default.asp

8. At Fort Hood, packaged HVAC units/equipment shall include factory installed LONWORKS® control hardware when/where this control option is available. Fort Hood's prefers that the contractor select packaged HVAC units that provide this control option.

9. Control sequence logic shall reside in DDC hardware in the building. The building control network shall not be dependent on connection to a Utility Monitoring and Control System (UMCS) for performance of control sequences in this specification. The hardware shall, to the greatest extent practical, perform the sequences without reliance on the building network.

10. The hardware shall be installed such that individual control equipment can be replaced by similar control equipment from other equipment manufactures with no loss of system functionality.

11. All necessary documentation, configuration information, configuration tools, programs, drivers, and other software shall be licensed to and otherwise remain with the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor,

12. The Contractor shall provide sufficient documentation and data, including rights to documentation and data, such that the Government or their agents can execute work to perform repair, replacement, upgrades, and

expansions of the system without subsequent or future dependence on the Contractor.

13. Hardware shall be installed and configured such that the government or their agents are able to perform repair, replacement, and upgrades of individual hardware without further interaction with the Contractor.

14. Control hardware shall be installed and configured to provide all input and output Standard Network Variables (SNVTs) as shown and as needed to meet the requirements of this specification.

15. All DDC devices installed under this specification shall communicate via EIA 709.1B. The control system shall be installed such that a SNVT output from any node on the network can be bound to any other node in the domain.

Appendix E: UMCS System Administrator, Tech Support Rep, and System Integrator SOW

Appendix E
<Post Name>
UMCS System Administrator[, Technical Support Representative,][and System Integrator]
Statement of Work

Specifier Note:

1. This SOW can be used to obtain "long-term" support of a UMCS and/or building control systems. Several tasks are included and the SOW must be edited to remove any tasks that are not desired. In general, this SOW can provide:

2. A technical service representative (TSR) embedded in the maintenance shop to assist with building control systems

3. A UMCS System Administrator to develop and maintain procedures for UMCS operation and the integration of building systems into the UMCS. This System Administrator may also perform the "day-to-day" tasks required to maintain the UMCS

4. A System Integrator to perform integration of building DDC systems into the UMCS. In this case this SOW must be editing to include the requirements of the *UMCS DDC Integration* SOW..

5. Some of the required entries to edit this SOW are in Word fields. To update these fields, click in the body of the document press Ctrl-A (to select all) then press F9 and you will be prompted for the correct information.

6. Entries in fields are in "< >" brackets and you will be prompted for them when you update fields. Entries requiring manual editing are in "[ ]" brackets.

7. These instructions and all specifier notes are in single cell tables – just delete the table when done editing this document.

8. A standalone version of this SOW in Microsoft Word format is available at the ERDC-CERL Building Automation Systems Team website at
https://eko.usace.army.mil/fa/bas/

Table of Contents

1. OBJECTIVE

The Contactor shall provide technical support to **<Post Name>**'s **<UMCS Manufacturer> <UMCS Model>** Utility Monitoring and Control System (UMCS). The Contractor shall:

> **Specifier Note:** The bulleted list includes a selection of tasks that can be covered by this SOW. Include the bullets and corresponding paragraphs for items you want as part of this SOW and remove the others.

- develop and document a System Integration Methodology
- develop and document a System Operation Methodology
- manage and operate the UMCS according to the Operation Methodology
- perform integration of building DDC systems according to the System Integration Methodology
- provide OMD-embedded maintenance support

2. REQUIREMENTS

<Post Name> currently has a **<UMCS Manufacturer> <UMCS Model>** Utility Monitoring and Control System installed in accordance with the requirements of UFGS 25 10 10. Unless otherwise indicated all requirements of this Statement of Work pertain to this UMCS. All work performed by the contractor shall ensure that the system is an Open, LNS-Based Flat LON system in accordance with UFGS 25 10 10. In cases where UFGS 25 10 10 allows options the Contractor shall coordinate these options with **<Post Name>**.

2.1. US Citizenship Requirements

Contractor must insure that all contractor personnel who will work on **<Post Name>** or have access to information that describes the **<Post Name>** Utility Monitoring and Control System (UMCS) must be United States citizens. Contractor will be responsible for insuring that all subcontractor personnel, at any tier, having access to information about the **<Post Name>** UMCS are United States citizens. The contractor is expected to secure all drawings or other descriptive information concerning the current **<Post Name>** UMCS so access is granted only to those who need the information to perform work under this contract.

2.2. Embedded Maintenance Support

> **Specifier Note:** Indicate the name of the maintenance shop (For example for Fort Bragg this is Operations Maintenance Division [OMD])
>
> The bracketed number of hours is for 1 year. Adjust as needed for more/less support.

The contractor shall provide a technical service representative (TSR) embedded in the **<Maintenance Shop>**. The embedded TSR shall maintain a physical presence in the shops according to a mutually agreed upon work

schedule for a total of [1800 hours] under this contract. The Contractor shall assign specific staff to perform the TSR services and shall not rotate staff in and out of the TSR role where the intent of this requirement is to maintain consistency. TSRs are not required nor expected to participate in maintenance support activities outside of or beyond the scope of this contract.

The TSR shall:

2.2.1. Provide maintenance support services for both new and existing control systems equipment and hardware. Intimate familiarity with LonWorks DDC Systems and with the **<UMCS Manufacturer>'s <UMCS Model>.** is required along with a working knowledge of other equipment and hardware such as pneumatics, analog electronic and single-loop digital control. The support requirements apply to all control systems regardless of whether or not the system is connected to the UMCS.

2.2.2. Assist **<Maintenance Shop>** staff with control system problem identification, diagnosis, maintenance, repair, installation, and commissioning. This includes the generation of service orders according to **<Maintenance Shop>** procedures. TSR shall pay particular attention to systems and equipment that is under warranty where the intent is to identify problems prior to warranty expiration and have repairs performed under warranty by the installing contractor.

2.2.3. Assist with in-house renovation projects including the development of project requirements, specifications, drawings, scope of work, cost estimates, bill of materials, installation, and inspection.

2.2.4. Provide scheduled and on-the-job UMCS and DDC training to **<Maintenance Shop>** staff. Scheduled training shall be classroom style at mutually agreed upon periodic intervals. The duration, scheduling, and content of scheduled training shall be mutually agreed upon by the TSR and **<Maintenance Shop>** maintenance staff.

2.2.5. Obtain and maintain a cell phone service and provide cell phone number to **<Maintenance Shop>** staff. TSR shall carry the phone at all times during the agreed upon work schedule and shall use this phone for communicating with **<Maintenance Shop>** staff.

2.2.6. Provide and be responsible for their own transportation vehicle, diagnostic equipment, and hand tools. Contractor owned vehicles shall meet the "Contractor Owned Vehicle Requirements" in Exhibit A.

2.2.7. Provide monthly activity summary reports. Reports should be brief summaries of activities performed for the month. These reports shall be organized as follows:

a. List of DDC Systems supported (as described in 2.2.1.)

b. Summary of **<Maintenance Shop>** staff assistance provided (as described in 2.2.1.):

    i.   problems identified for warranted systems

    ii. commissioning support provided

    iii. other support activities

c. Summary of assistance provides to in-house renovation projects (as described in 2.2.2.)

d. Summary of training provided (as described in 2.2.3.) including dates, times, attendance and content of scheduled and on-the-job training sessions.

2.3. UMCS Operation and Management

2.3.1. UMCS Operation Methodology

The Contractor shall develop and document a UMCS Operation Methodology. As part of this the Contractor shall coordinate with DPW and **<Maintenance Shop>** staff in the identification and development of processes for operation of the UMCS and shall implement mutually agreed upon processes. The processes shall take into consideration the current and future anticipated needs and uses of the UMCS. These processes include, but are not limited to:

Specifier Note: Include a list of computers that must be able to access the UMCS.

---

a. DPW and **<Maintenance Shop>** access. Fort Bragg needs access to the system according to defined procedures and logistics including but not limited to password levels/limits and access to and training on tools. Coordinate with the installation Directorate of Information Management (DOIM) to ensure that the following computers can access the UMCS: [LIST OF COMPUTERS].

b. DPW Tools. Describe a methodology for Operation Maintenance Division (OMD) access to and use of the UMCS and related tools such as laptops including OMD responsibilities and obligations.

c. Service Calls. Define the process whereby the UMCS Contractor responds to requests for information and diagnostic actions to be taken by the UMCS operator in response to calls from maintenance staff who are troubleshooting DDC systems that are connected to the UMCS.

d. Alarms. Define the process whereby alarms received by the UMCS from DDC systems connected to the UMCS are selected, setup, monitored, routed, and managed. This includes the generation of work orders based on received alarms.

e. Energy Savings. Define the process for reducing energy consumption, tracking energy savings, data archiving, and trending towards meeting LEED goals and standards along with the creation and management of equipment usage and performance reports.

f. UMCS Training. Identify and define training needs and requirements for DPW staff. Note: The contractor shall provide UMCS training as specified in UFGS 25 10 10.

g. Installation Design Guide (IDG). Installation Design Guide (IDG). The Contractor shall provide verbiage for suggested changes to Fort Bragg IDG in support of an open basewide UMCS and in support of its successful management, operation, and maintenance.

2.3.2. UMCS Operation and Management

The Contractor shall manage the UMCS in a manner consistent with the requirements and intent of UFGS 25 10 10, UFGS 23 09 23 and the following requirements:

a. Systems Integration Log. The Contractor shall develop and maintain an up-to-date log consisting of:

i. Documentation drawings and submittals specified in UMCS UFGS 25 10 10 for the UMCS.

ii. Documentation drawings and submittals specified in DDC UFGS 23 09 23 for DDC systems connected to the UMCS or those for which future connection is anticipated.

iii. Related documentation as specified in this SOW.

iv. System Administrator and Information Assurance documents, records, and certification data.

v. Maintenance and repair records.

vi. Meeting minutes

These items are further described below.

b. Documentation. The Contractor shall compile, manage, store, and maintain UMCS and related DDC system documentation. As part of this the Contractor shall assist the DPW to identify, locate, and assemble existing UMCS and DDC materials that will facilitate the implementation of the UMCS as a basewide system such DDC system drawings, LNS databases, Points Schedules, technical references, etc.

c. System Administrator. The Contractor shall serve as a system administrator for the UMCS (on the Army enterprise network) and UMCS computers and shall obtain all necessary training and certifications and otherwise meet Information Assurance requirements as described in Exhibit A for the Contractor staff

and for the UMCS as needed to perform system administrator duties for the UMCS.

d. Maintenance and Repair. The Contractor shall maintain the UMCS including:

   i. Maintenance and repair of hardware

   ii. Maintain all UMCS related software including Monitoring and Control software and Network Configuration Tool software including up-to-date patches, fixes, upgrades

   iii. Perform database backups

   iv. Maintain user accounts and permissions

   v. Update UMCS with applicable data as needed from other computers systems such as automatic meter reading, electrical distribution SCADA, etc.

   vi. Provide data to other computer systems or personnel as needed

e. DDC Contractor Coordination. The Contractor shall work with DDC contractors to clarify open system and integration requirements and demonstrate the UMCS.

f. Meetings and Reviews. The Contractor shall attend the monthly **<Post Meeting>.** UMCS Workgroup meetings. The Contractor shall attend design and planning charrettes and shall review UMCS and DDC-related designs for Military Construction and other funded projects. The Contractor shall review DDC system submittals from third party DDC system contractors to determine if the DDC system meets the requirements of the System Integration Methodology. The Contractor may provide recommendations to the government but will not be permitted nor be responsible for accepting or rejecting other Contractors work or submittals. The Contractor shall provide minutes for all meetings held with the government.

2.4. System Integration

2.4.1. System Integration Methodology. The Contractor shall develop a System Integration Methodology in accordance with the open system requirements in this SOW, UMCS UFGS 25 10 10, and the applicable integration-related requirements of DDC UFGS 23 09 23. The methodology shall describe the technical approach for accomplishing the integration of DDC systems installed in accordance with DDC UFGS 23 09 23 including those installed by third-party contractors. The description shall include all elements contained in this SOW including but not limited to:

a. Government Coordination. Describe the coordination procedures including that with, at a minimum, the following Government personnel:

- DPW, Energy Manager: name, phone, e-mail. Role/responsibility.
- DPW, Chief of O&M: name, phone, e-mail. Role/Responsibility.
- DPW, Shop Foremen: name, phone, e-mail. Role/Responsibility.
- DPW, Shop Work Leaders: name, phone, e-mail. Role/Responsibility.
- DOIM: names, phone, e-mail. Role/Responsibility.
- District Office Engineer: names, phone, e-mail. Role/Responsibility.
- Area Office Engineer: names, phone, e-mail. Role/Responsibility.

b. UMCS Connectivity. Describe the procedure for providing the BPOC and obtaining the IP connection. For example, will the UMCS Contractor install the ANSI/EIA 709.1 to IP ANSI/EIA 852 router to connect the building level control system to the base-wide IP network? Alternatively, the SIM may call for the UFGS 23 09 23 Contractor to provide the router as part of the building level contract -- the actual approach must be defined in the SIM.

c. LNS Database. Describe the procedure for managing the UMCS LNS database(s) including the approach for integration of UFGS 23 09 23 systems. For example, should building contractors work directly from the basewide LNS database? Will building databases be merged to create a single basewide database or maintained as separate databases? What guidelines will be used to determine when databases are or are not merged? Will DSN addresses need to be reassigned? Will a separate database be assigned to each third-party contractor?

d. UMCS Integration Checklist. Develop a checklist of activities and describe information to be provided by the UMCS Contractor to third-party DDC UFGS 23 09 23 contractors that is needed by these third-party contractors in order to perform successful integration with the UMCS, such as domain names and addressing. List and describe submittals and technical information needed from third party contractors in order to accomplish integration of third-party UFGS 23 09 23 systems.

e. DDC Integration Checklist. Develop a checklist of activities and describe information to be provided by the DDC UFGS 23 09 23 Contractor to the UMCS Contractor that is needed by the UMCS Contractor to perform successful integration with the UMCS. This might consist of: LNS database handling and submission, LNS Plug-ins submittals, XIF and other resource file submittals, software licenses and LNS credits, programming software and source code submittals, verifying required

SNVTs per Points Schedule drawing, Verify/add bindings as needed, verifying override points defined/available, Points Schedule drawing submittal, Riser Diagram drawing submittal. Potential/expected recommissioning of field devices (obtaining field data, not sending it).

f. M&C Software Configuration. Provide step-by-step description for programming, configuring and otherwise setting up hardware and software to accomplish Monitoring and Control software functionality specified in UFGS 25 10 10 so as to accomplish integration of third-party UFGS 23 09 23 systems. This shall include obtaining or development of a Points Schedule drawing for the system to be integrated.

g. Acceptance and startup procedures. Describe any inspections or testing to be performed to verify that the interface between the UMCS and the third-party building-level system can be accomplished.

2.4.2. UMCS DDC Integration. The contractor shall integrate LNS-based LonWorks DDC systems into the UMCS. System integration shall be in accordance with the following:

Specifier Note: If you keep this UMCS DDC System Integration option, copy paragraphs 3, 4 and 5 from the 'UMCS DDC Integration SOW' into this SOW so as to specify/define the integration requirements.

Also, complete the bracketed option defining the scope of the integration services that the contractor shall provide. This can be done by listing buildings or systems, by number of graphic pages and points or by specifying a number of hours (level of effort). Use caution when specifying as a number of hours since there is no easy metric to measure if the contractor is "dragging his feet".

The contractor shall provide integration services for [_____].

3. DELIVERABLES

Specifier Note: The current (bracketed) due dates for the deliverables assumes this is a 1-year contract. Edit the due date for all deliverables to reflect actual requirements.

Unless otherwise noted below, each of the below submittals shall be in editable electronic format on CD-ROM (no PDFs unless otherwise approved) and in hardcopy format.

3.1. Embedded Technical Service Representative (TSR) Activity Summaries

[Monthly activity summary report for each month due on the 5th day of the following month except that the summary report for the last month of this contract is due on the last day of the performance period.]

3.2. UMCS Operation Methodology

Initial submittal   [3 months after award]

Final submittal   [2 months prior to contract completion]

3.3. System Integration Methodology

Initial submittal   [3 months after award]

Final submittal   [2 months prior to contract completion]

3.4. Systems Integration Log

Initial submittal   [6 months after award]

Final submittal   [2 months prior to contract completion]

3.5. Meeting Minutes

Meeting minutes shall be delivered via email within 1 week after each meeting.

4. PERIOD OF PERFORMANCE

Specifier Note: Specify the duration for the project. If you specified a number of hours for a TSR or for DDC UMCS Integration make the completion of the project allows enough time for those hours.

Completion of this project will be [____].

5. DISTRIBUTION

Specifier Note: Specify distribution for all deliverables.

Distribution for all deliverables of this project will be [___]

Exhibit A: Network Access Requirements

Specifier Note: The System Administrator will need to work on a Government computer system to perform the requirements of this SOW. Coordinate with the installation DOIM to identify any requirements that the contractor must meet in order to access Government networks and computers and include them here. The below text is from a SOW generated by Fort Bragg and is included as an example only.

Example Network Access Requirements For U.S. Government Contracts

1. Information Assurance (IA). Contractor personnel requiring access to U.S. Government Information Systems to fulfill their duties shall possess the required favorable security investigation, security clearance, formal access approval, and need-to-know prior to being granted access to any Government computer or computer network.

2. IT-I Level of Security Access is required for Contractor personnel in IA Position working with infrastructure devices, IDSs, routers, System Administration or Network Administration, with privileged-level access to control, manage, or configure Information Assurance tools or devices, individual information systems, networks, and enclaves. At a minimum, such Contractor Personnel shall require a favorably completed NAC, initiation of SSBI, completion of SF85P, SF86, and Supplemental Questionnaire.

3. IT-II Level of Security Access is required for Contractor personnel in IA positions requiring the work with operating systems administration of common applications or enclaves, or back-up operators, with limited privileged level access to control, manage, or configure information systems or devices. At a minimum, such contractor personnel shall require a favorable review of local personnel, base/military, medical and other security records as appropriate, initiation of a NACLC, and completion of the SF85P or SF86 and Supplemental Questionnaire.

4. IT-III Level of Security Access is required for Contractor personnel in positions as normal users, power user on individual systems for configuration with non-privileged level of access to information systems and devices. At a minimum, such contractor personnel shall require a favorable review of local personnel, base/military, medical and other security records as appropriate, initiation of a NAC, and completion of the SF85P and Supplemental Questionnaire.

5. Contractor personnel shall not be granted access to any Government computer systems or networks until proof of compliance to the Information Assurance (IA) clearance requirements.

6. Once Contract personnel have complied with the Information Assurance requirements as reflected above, they will be granted the appropriate Information Technology level of security access.

7. Contractor Personnel shall personally pick-up and sign for Government network user identification and password at the 1112th Signal Battalion Information Assurance Office.

8. Contractor Employee(s) shall be solely responsible for the safeguarding of user passwords, and shall immediately report any suspected compromise or loss of password to the 1112th U.S. Army Signal Battalion Information Assurance Office, Building 1-1554.

9 The Contractor is responsible for notifying the Contract Officer Representative (COR) and also the 1112th U.S. Army Signal Battalion Information Assurance Office of any changes to their or their personnel' status.

Appendix F: UMCS DDC Integration SOW

<Post Name> **UMCS DDC Integration**

Statement of Work

[project number / identifier]

[date]

Specifier Note:

1   This SOW can be used to obtain system integration services to integrate an LNS-based LonWorks building control system into an LNS-based LonWorks UMCS.

2   For MILCON projects this SOW can be used by having the district MIPR projects funds to a contracting entity to award the integration services. For example, at Fort Bragg:

    a.   Savannah District (SAS) completes this document (bracketed options) and sends it along with the noted attachments to Huntsville (HNC).

    b.   HNC obtains integration pricing based on this SOW.

    c.   SAS MIPRs the required funds to HNC to award the contract/task order.

3   Some of the required entries to edit this SOW are in Word fields. To update these fields, click in the body of the document press Ctrl-A (to select all) then press F9 and you will be prompted for the correct information.

4   Entries in fields are in <> brackets and you will be prompted for them when you update fields. Entries requiring manual editing are in [] brackets.

5   These instructions and all specifier notes are in single cell tables – just delete the table when done editing this document.

1.0 SYNOPSIS: The Contractor shall provide the materials and labor required to integrate direct digital control (DDC) systems into the **<Post Name>** base-wide **<UMCS Manufacturer> <UMCS Model>** Utility Monitoring and Control System (UMCS).

2.0 PRICE PROPOSAL: The Contractor shall provide a firm fixed price proposal for the integration of the Direct Digital Control (DDC) systems specified below into the **<Post Name>** Utility Monitoring Control System (UMCS).

> Specifier note: System integration should be done in accordance with the System Integration Methodology (SIM) if the installation has one. Include the bracketed text if the installation has a SIM and remove it otherwise.

3.0 SPECIFIC WORK TO BE ACCOMPLISHED: The Contractor shall provide materials and labor required to integrate LNS-based LonWorks Direct Digital control (DDC) systems specified into the **<Post Name>** Utility Monitoring Control System (UMCS). All work shall be in accordance with [the approved **<Post Name>** System Integration Methodology,] and Unified Facilities Guide Specification (UFGS) 25 10 10 and this SOW. All work performed by the contractor shall ensure that the system is and remains an Open, LNS-Based Flat LON system in accordance with UFGS 25 10 10. In cases where UFGS 25 10 10 allows options the Contractor shall coordinate these options with **<Post Name>**.

    3.1 The contractor shall integrate the following building DDC systems:

> **Specifier note:** Identify all systems to be integrated. If BPOC Locations and IP Addresses are going to be listed in this SOW (as opposed to on a drawing or requiring coordination – see next specifier note) you may want to put a table here showing this information as well. For example:
>
> | System | BPOC Location | BPOC IP Address |
> | --- | --- | --- |
> | Bldg 52 West Wing | Bldg 52, room 215 | 192.168.2.101 |
> | Bldg 52 East Wing | Bldg 52, room 215 | 192.168.2.105 |
> | Bldg 62 AHU 1 | Bldg 62, room 410 | 192.168.2.108 |

        3.1.1   [list the DDC systems and/or buildings]

    3.2 For each DDC system the contractor shall perform all tasks required to fully integrate the system into the UMCS including but not limited to:

        3.2.1   Install an ANSI/CEA 709.1 to ANSI/CEA 852 router Building Point of Connection (BPOC) to connect the building DDC system to the UMCS IP backbone.

Specifier note:

Provide BPOC locations by one of the following:

- Include a drawing/document with these locations with the SOW
- List the locations (building/room number) here.
- Refer to the table (see previous specifier note) where they are listed.

Similarly, provide IP addresses for the BPOC. Note that the IP addresses may not be known pre-award in which case choose either to provide them to the contractor post-award or require that the contractor obtain them from DOIM. If requiring the contractor to obtain them from DOIM provide a DOIM point of contact.

Note that this SOW assumes that the BPOC location is the location of the IP drop provided by DOIM.

3.2.1.1 BPOC locations are [shown in the Government furnished documents] [_____].

3.2.1.2 BPOC IP addresses [are shown in the Government furnished documents][will be provided after contract award][shall be obtained from **<Post Name>** DOIM. DOIM POC is [_____]][___]

3.2.2   Incorporate each DDC system LNS database into the UMCS database:

Specifier note: Include bracketed text referring to the system integration methodology if the installation has one, otherwise remove the bracketed text.

3.2.2.1   Merge the building database into the UMCS database or establish a new LNS database at the UMCS as required to maintain UMCS performance [and in accordance with the System Integration Methodology].

3.2.2.2   Install and update LNS plug-ins in the **<Post Name>** LNS network configuration tool.

3.2.2.3   Configure **<Post Name>**'s LNS network configuration tool (NCT):
- Upgrade NCT licensing as required.
- Configure NCT drawings and displays, if applicable, to clearly display building DDC systems.

3.2.3   Incorporate each DDC system into the UMCS Monitoring and Control Software:

3.2.3.1 Create graphic display pages for each DDC system:
- To the greatest extent possible graphics for similar systems shall be the same.
- Graphics shall provide monitoring and override points as shown on the Points Schedules.

3.2.3.2 Configure Scheduling, Alarming and Trending functionality for the building system as shown on the Points Schedules.

3.2.3.3 Configure supervisory control functions such as demand limiting, load shedding or optimum start/stop, if applicable.

3.2.4 Create network variable bindings for communication between building systems, if applicable.

3.2.5 Reconfigure building DDC devices that poll for network variables, particularly Local Display Panels (LDPs), to use the new domain-subnet-node addressing for the building DDC system.

3.3 Contractor shall demonstrate completed integration to the Government. This demonstration shall show all work performed and shall be sufficient to familiarize the Government the interface to the integrated systems.

4.0 GOVERNMENT FURNISHED INFORMATION:

Specifier note: Include all drawings and documentation required to document the building system for integration. The following list contains some suggested drawings, not all of which may be needed. For example, the ductwork layout drawing may not be needed by the integrator if user displays do not include ductwork information.

4.1 Control system drawings notably including the Points Schedule drawing(s)

4.2 [Floor plan drawings]

4.3 [Ductwork layout drawings]

4.4 [Mechanical drawings]

4.5 [Electrical drawings]

4.6 [Other drawings as indicated by **<Post Name>** or the **<Post Name>** System Integrator]

> **Specifier note:** The integrator is required to update licensing and drawings in the network configuration tool (NCT). This may require them to purchase additional licensing and requires knowledge of the particular NCT the installation uses. Provide documentation of the NCT, including information on the licensing (if the software requires licenses, how many if has, how many are used etc) so that the integrator can determine the cost/effort involved in meeting this requirement.

4.7 [Network Configuration Tool (NCT) licensing information including NCT model, manufacturer, revision and license status.]

5.0 DELIVERABLES:

5.1 Summary listing of all M&C software edits, changes, and updates accomplished as part of system integration. Format shall be: Hardcopy and MS-Word or PDF on CD-ROM.

5.2 Product data including product data sheets and computer software supplied under this contract as specified in UFGS 25 10 10. Format shall be: Hardcopy and MS-Word or PDF on CD-ROM of all data sheets, plus computer software on CD-ROM.

5.3 Licensing information for all software provided or modified as under this contract as specified in UFGS 25 10 10. Format shall be: Hardcopy and electronic file on CD-ROM.

5.4 *Final As-Built Drawings* as specified in UFGS 25 10 10. Format shall be: 11x17 inch hardcopy and MS-Excel on CD-ROM.

> **Specifier note:** Provide the notification time which must be given for the demonstration of the integration and who must be notified.

6.0 SCHEDULE: The performance period shall be from **<expected date of DDC system completion/acceptance>** until **<two months from start or period of performance>**. Notice of demonstration of completed integration shall be given to [point of contact] no less than [one week] before demonstration. Schedule impacts, for any cause, will be brought to the attention of **<the COR>** and the Contracting Officer immediately. The contractor shall provide a proposed resolution and basis for delay.

Appendix G: DDC Integration Process via MIPR

This document is a draft of the process through which new direct digital control (DDC) systems are integrated into the Fort Bragg Utility Monitoring Control System (UMCS). The process defines the roles and responsibilities of Fort Bragg (Bragg), Huntsville Support Center (HNC), and Savannah District (SAS). In general, the basic approach includes SAS issuance of a MIPR (using construction project funds) to HNC who in turn awards a contract for system integration.

Note that the steps listed here describe what must be done but do not specify all details on how each organization will accomplish that task. For example, Item 1 does not identify *how* SAS confirms/assures that funding is programmed – it is expected that SAS knows how to do this and will be able to do so.

Table 2. Steps for obtaining integration.

#	Step	Comments / Notes
1.	In the planning stage SAS confirms/assures that there are funds programmed for UMCS integration and sets aside 0.5% of the facility cost to pay for system integration. More definitive/accurate pricing may be identified after the first several projects have been completed.	
2.	In the planning stage SAS sends an email alert to HNC and Fort Bragg that a UMCS DDC integration project is being planned. -Email subject line: [Bldg or project number] integration to UMCS -Email content: Notify HNC that a request for UMCS DDC integration services is forthcoming and to provide an estimated date when the integration services SOW (described in step 3) will be sent to HNC. Advance notification to Fort Bragg DOIM that an IP drop and IP address on the controls VLAN will be needed and will be officially requested later (see step #7).	Send email to: HNC: Donnie.R.Lambert@usace.army.mil Fort Bragg DOIM: jose.troche1@us.army.mil Cc: steven.m.dunning@us.army.mil jennifer.mckenzie@us.army.mil

#	Step	Comments / Notes
3.	Once the design has progressed to the appropriate point: SAS sends the 'UMCS DDC Integration SOW' to HNC so that HNC can obtain pricing for the integration. Additional requirements and details may well be identified after Fort Bragg has established their UMCS. Consequently, the SOW may need to be updated. For example, floor plan ductwork drawings may need to be provided to support development of UMCS graphical displays that show spaces/zones serviced by each air handler. SAS indicates (in the UMCS DDC Integration SOW or body of the email) the planned/desired location of the IP drop. SAS is the owner of the UMCS DDC Integration SOW and will maintain/update it as needed.	Send SOW to: HNC Donnie.R.Lambert@usace.army.mil Fort Bragg DOIM: jose.troche1@us.army.mil
4.	HNC obtains pricing for integration based on the SOW provided by SAS in step 3.	.
5.	HNC provides cost/pricing to SAS including: Cost for Integration, HNC admin/contracting fees, contract management, and any technical assistance/reviews necessary. HNC technical staff will serve as the HNC contracting officer's technical representative (COTR) and provide quality verification (QV) services including verification that all work described in the UMCS DDC Integration SOW has been performed/accomplished. HNC shall oversee implementation of all related Integration steps (via in-house staff or Contract) in this System Integration Process (such as coordination with DOIM to obtain IP drop, etc.). It is anticipated that, over time, portions or all of this responsibility may be transferred to Fort Bragg DPW staff (such as an OMD staff member)	
6.	SAS MIPRs funds to HNC. MIPR wording: Provide integration services as described in UMCS DDC Integration SOW dated [_____].	
7.	UMCS Information Management Officer (IMO) requests an IP drop and IP address on the controls VLAN for the BPOC and includes the estimated occupancy date in the request.	

#	Step	Comments / Notes
8.	SAS turns the building over to Fort Bragg after the following tasks have been completed: SAS completes building construction including Performance Verification Test (PVT) and applicable Commissioning of the building control system(s). SAS verifies that the LonWorks open system requirements have been met. This may be accomplished using the LonWorks Compliance Assessment Tool being developed via CERL/HNC direction/contract.	
9.	System Integration Contractor can begin the integration process – installation of new servers, graphic creation, etc.	
10.	DOIM installs IP drop	
11.	System Integration Contractor installs BPOC and completes integration of building controls to UMCS.	

Appendix H: Example Implementation Plan

IMPLEMENTATION PLAN

For

[FORT BRAGG]

BUILDING AUTOMATION SYSTEM

(draft 4/2/07)

Workgroup Members

- Steve Dunning, Facilities Maintenance Division (FMD) Work Leader
- Ashley Gore, FMD Work Leader
- Russ Hayes, DPW Mechanical Engineer
- Derrick McRae, Mechanical Engineer
- Jennifer McKenzie, Energy Manager
- Tom Patrick, FMD Work Leader
- David Taylor
- Jose Troche (DOIM)
- Vic Walker, Operations Maintenance Division (OMD) Operations Officer
- Wilhelmina Pierce (Corps of Engineers [COE])

Purpose

The purpose of this document is to describe [Fort Bragg's] basewide BAS including the goals, features, and benefits of the BAS along with a strategy for successful implementation, use of, and support of the BAS.

Note: This document makes reference to Unified Facilities Guide Specifications UFGS-13801 and 15951, which have been assigned new numbers; UFGS 25 10 10 and 23 09 23, respectively.

Problem

[Fort Bragg] has two basic problems:

1. Multiple brands of Direct Digital Control (DDC) systems that are not integrated into a common single-interface user-friendly system. There are cur-

rently three "enterprise" systems with no overall plan to integrate all systems into an installation wide system or connect the new "smart" buildings.

a. Honeywell Inc. has an onsite presence at the Energy Information Center. Through an ESPC Honeywell uses their Enterprise Buildings Integrator (EBI) platform, which is interfaced to 165 building-level control systems (installed by Honeywell) including approximately 50,000 points and approximately 280 energy meters (electricity, gas, water). Honeywell has installed nine EBI-related servers. Four of these (CoGen plant, JSOC, Main, and Energy Center) are networked to the servers at the Energy Information Center, the other five are not. There are 14 workstations located at the Central plants, Work Order Center, and the Energy Information Center). Currently the system software license includes 12 simultaneous users per server with up to 40 licensed users possible (per server). there is no contractual arrangement to obtain system integration services to integrate new (Honeywell or 3rd party) LONWORKS® building-level systems to the EBI front-end. The EBI system includes proprietary elements including 88 Tridium JACE and 96 Honeywell C-bus controllers where each of these is at the "building level." The JACE and C-bus devices do not accommodate a logically flat TP/FT-10 network connection (where the logically flat network is currently the preferred open systems approach). Reportedly, JACE devices are no longer being installed as it appears Honeywell is transitioning towards a logically flat architecture. There are 143 LONWORKS® controllers and 15 distributed input/output (I/O) LONWORKS® devices. The distributed I/O LONWORKS® devices are interfaced to Honeywell Excel 500 controllers in a supervisory configuration thus not part of a logically flat LONWORKS® network. In addition, some of the Excel 500 controllers are on C-bus network (not a TP/FT-10 LONWORKS® network). Similarly there are Excel 50 controllers also on a C-bus network. Both the Excel 50 and 500 are configurable to accommodate a TP/FT-10 network connection via a card/slot on the controller. (Information is current as of Mar 07)

b. JCI has an onsite office that services Bragg and other clients. Through "UMCS II" contract awarded by Huntsville, JCI has installed a number of LONWORKS® systems. Some of the early systems used the proprietary NAE supervisory controller device at the building-level. Later systems reportedly use the JCI flat LONWORKS® architecture and therefore are (should be) in accordance with intent and requirements of UFGS

25 10 10 and 23 09 23. The systems installed by JCI include 33 build-
ings that use JCI proprietary N2 communications bus and 62 buildings
that use LONWORKS® (presumably TP/FT-10 bus). The first 10 build-
ings installed under EMCS II contract were N2, the rest used
LONWORKS® TP/FT-10. There are two LONWORKS® Control Station
(LCS-8520) front-end operator workstation computers and a server,
but these workstations are not "on the network" as the JCI system
awaits DITSCAP (DOD Information Technology Security Certification
and Accreditation Process) (or equivalent DIACAP) certification. In
addition there is no contractual arrangement to obtain system integra-
tion services to integrate new (JCI or 3rd party) LONWORKS® building-
level systems to the LCS front-end. (Information is current as of Mar
07)

c. Yamas. Pope Air Force Base (AFB) through a Utility Energy Services
Contract (UESC) installed a Yamas (Tridium/JACE) system including
approximately 74 buildings and 126 meters. Pope AFB becomes part of
Fort Bragg through Base Realignment and Closure (BRAC) around
2011.

2. In addition to the enterprise-level systems described above, individual
building-level DDC systems are procured on a routine basis. The individ-
ual multi-vendor systems are often provided with laptops, PCs, and soft-
ware tools resulting in overwhelming complexity due to the ordinary com-
plexity of DDC technology compounded by multiple tools from multiple
manufacturers. For example, Fort Bragg has 14 different DDC system lap-
tops.

The end result is potentially very useful mix of building automation sys-
tems that are of limited effectiveness to routine DPW operations in part
because the DPW has only limited or no access to the Honeywell and JCI
systems. Limitations include access to the operator workstations for the
O&M activities and energy manager support functions.

Goals and Benefits

The overall goal is to obtain a basewide BAS consisting of a UMCS (front-
end) and local control DDC systems that functions as a single integrated
system. The BAS must be manageable and maintainable. It must also be
usable by and functional for the Operations Maintenance Division (OMD),
the energy manager, and others. Over the long term the BAS must grow

with the needs of the DPW and evolve into a fully functional tool that is supportable by and useful to OMD.

The BAS will perform and support the following functions:

- Remote monitoring of buildings. Provide O&M staff and others the capability to easily:
    - Display real-time system/equipment performance
    - Set up and collect trend data (for example; historical temperature data)
    - Set up alarm points including routing of alarms to appropriate personnel while avoiding the creation and generation of nuisance alarms
- Improve service order process especially for HVAC
    - Analyze the problem remotely and send the correct technician
    - Identify the potential problem before arrival onsite
    - Energy Monitoring and Control System (EMCS) alarms generate service orders, without increasing backlogs
    - Transition from reactive to proactive environment
- Improve customer service by improving response time and situational awareness before arriving on site. Ideally the DPW identifies problems before the customer is aware of situation.
- Improve building occupants comfort level
- Identify problems initially when they are small and cost less to fix instead of complete replacement due to system failure.
- Support energy savings
    - Temperature set backs during nights and weekends including scheduled start-stop of air handling units
    - Monitoring of energy usage and cycling of mechanical and electrical equipment during energy peaks to reduce electrical power demand
    - Improved maintenance and thus performance of equipment
    - Automate other processes such as parking lot and baseball field lighting
- Generate reports.

BAS Characteristics

General Description

The [Fort Bragg] BAS will be based on open systems technology specified in two Unified Facilities Guide Specifications including LONWORKS® technology and ANSI/CEA standard 709.1 communications protocol. One is for building level controls used when a facility is designed and constructed. This is UFGS 23 09 23, Direct Digital Control (DDC) for HVAC and Other Building Systems is for building level controls used when a facility is designed and constructed. The other is UFGS 25 10 10, Utility Monitoring and Control System for a "front end" or a base wide interface to the building level systems. Both of these specifications are intended to specify and procure as open a system as is possible. An open system is one where there is no future dependence on the original installing contractor. For the purposes of procurement, this means that there is no sole source dependence on any contractor for future system additions, upgrades, or modifications. An open system helps to avoid proprietary sole source procurement in accordance with government procurement rules. In practice, single-source procurement is usually necessary for the UMCS, but can be avoided for the building-level DDC systems. In the case of the UMCS, the procurement of the base wide UMCS can be open competition resulting in a single provider over an extended term. This is discussed under "Path Forward."

Operator Workstations and Server(s)

There will be multiple operator workstations (OWS) for: OMD chief, OMD shop supervisor, OMD work leaders, OMD common area for use by OMD staff, Energy Manager, and DPW Director with several levels of password access to the various features. A web-based Graphical User Interface (GUI) will be considered. Workstations will display information and graphics as specified in UFGS 25 10 10 including floor plans (except for sensitive areas such as SKIFs)

LDPs

There will be a local display panel (LDP) mounted on or in each enclosure located in a mechanical room. LDPs can permit both display and adjustment of certain control system parameters such as control inputs, outputs,

and setpoints. The UFGS 23 09 23 guide specification calls for the designer to decide and thus specify if LDPs will permit display, adjustment, or both display and adjustment of parameters. This decision should be made based on maintenance staff input. Specifying the functionality is accomplished by showing the required functions in a Points Schedule drawing where this drawing is referenced in UFGS 23 09 23. This, along with other designer options contained in the UFGS 23 09 23 specification should be reviewed by the DPW so that the DPW and particularly the maintenance staff have an opportunity to provide input to system design and specification. These preferences should be documented in the IDG.

IT network

The BAS will use the existing high speed basewide IT network for communication between building-level DDC systems and the UMCS workstations. All applicable hardware and software will have DOIM/DITSCAP (DIACAP) approval/certification. Wireless technology will be considered where the existing IT infrastructure is not suitable (for example, due to cost). Wireless communication could drastically reduce some of the capital cost, but it currently is not approved at the Army installation level. There are a lot of hurdles. Wireless is not currently authorized to access the domain and will need DITSCAP Interim Authority To Operate (IATO) approval. The installation does not have the backbone communication infrastructure to support wireless transmission especially for WiMax.

Building Control Network

All project will include a TP/FT-10 building control network and all DDC devices will be connected to this network. Building-level designs will show the proposed location of the Building Point of Connection (BPOC) (to be installed by the System Integrator) and the TP/FT-10 network cabling (installed by the building-level contractor) will extend to that location. The BPOC (CEA 852 router) locations shall not be in communication closets. They may be in electrical closets or in approved mechanical rooms in approved and appropriate enclosures.

Laptops with NCT

The primary O&M tool will be a laptop with a network configuration tool (NCT) software. Five individuals within OMD will possess NCT laptops.

Software

Other software packages provided by Contractors (such as programming software) will reside with the system integrator (and one OMD POC). Programming software should only be needed to initially program "programmable" controllers (by the installing Contractor). All programmable controller settings necessary for O&M activities will be exposed as LONWORKS® SNVTs or Configuration Property Types (CPTs) and thus accessible using the NCT or OWS.

Controllers

Controllers come in two basic varieties: programmable and application specific. Programmable controllers will be avoided. Complex applications may require them, but as a rule application specific controllers (ASCs) will be given preference. Contractors will be encouraged to use ASCs due to their relative simplicity. Programmable controllers with plug-ins will be given preference over those without plug-ins. Note a plug-in is a software tool that can be launched from the NCT and can be used to remotely reprogram a programmable controller). ASCs will be provided with plug-ins as specified in UFGS 23 09 23. This requirement must be enforced by the USACE Construction office.

Miscellaneous

Controls and equipment must be maintenance accessible. Equipment must be appropriate. The Workgroup will generate a list of requirements and pursue incorporating these requirements into the IDG.

Control Devices and Interfaces

- Pneumatic actuation of valves and dampers is preferred over electric actuators due primarily to reliability and simplicity. Positive positioners should be avoided unless deemed necessary for the application (for example, due to the need for moving large volumes of air or for device sequencing).
- Filter alarms. Differential pressure switches used to sense loaded (dirty) air filters are problematic (for a variety of reasons). The current preference is to not use these, but instead generate a time-based low-priority alarm (perhaps via e-mail) where, for example, after 3 months

an alarm is generated to notify OMD that a particular filter is due to be changed.

- Fan coil unit condensate drain overflow switch monitoring and alarm.

Additional preferences may/will be added as they are identified.

UMCS Management

The UMCS will be managed by the System Integrator (SI) and by the UMCS Workgroup (or their designated in-house individual) and with clear distinction of roles and responsibilities. The Workgroup will define SI roles and responsibilities and will identify a mechanism to obtain these long term services. In summary, the SI will review DDC submittals, manage DDC Contractor submittals (Points Schedules, LNS plug-ins, LNS databases, XIF files), integrate new/renovated DDC systems into the BAS, maintain the LNS database, update the Graphical User Interface (GUI) for added buildings, manage the overall maintenance of the UMCS (software updates, etc.), coordinate all networking activities with DOIM, and manage and maintain laptop hardware and software.

Systems Integration and Support

A system integrator (SI) will be perform systems integration and UMCS management services as defined above under UMCS Management. In addition, the SI will provide support services potentially including embedding technical staff with OMD to provide operation and maintenance support and on the job training. SI requirements need to be further defined as described under Path Forward.

Support Structure

Successful design, specification, procurement, operation, maintenance, and expansion of the [Fort Bragg] BAS includes the following support structure:

- *UMCS Workgroup.* Defines and executes the Implementation Plan. Holds periodic meetings to assess progress, make changes to the plan as necessary, and provides general oversight and management of the BAS.
- *System Integrator.* Performs UMCS management and integration services.

- *Directorate of Public Works (DPW) Engineering Design*. Will work with the Workgroup to define BAS specifications for in-house designs. These specifications must be tailored to the specific contracting mechanism where these mechanisms include: [Job Order Contract,]
- *Directorate of Contracting*. May be needed to help identify a contracting vehicle to obtain the initial UMCS and the long term services of a Systems Integrator (SI).
- *Directorate of Information Management (DOIM)*. Will work with the Workgroup and the Huntsville Contractor to identify DOIM requirements. This will result in pertinent requirements to be included in BAS project specifications along with an agreement between DOIM and the Workgroup on methods and procedures to be followed.
- *DPW Master Planning Office*. Will work with the Workgroup to ensure that the Installation Design Guide (IDG) reflects requirements for the BAS.
- *DPW Maintenance Staff*. Provides input to Workgroup. Reviews the Implementation Plan. Designated OMD staff will be trained as DDC Specialists. The training will include basic laptop usage, NCT software, LNS-plug-ins, DDC system acceptance procedures. All OMD HVAC O&M staff will be trained on basic PC usage and fundamental usage of the centrally located OWS (how to pull up and view points and alarms).
- *USACE District Office Engineering Design*. Ensures that designs for new facilities and renovations of building control systems are consistent with the Implementation Plan. Reviews the Implementation Plan.
- *USACE Construction Office*. Works with Workgroup to develop a Building Acceptance methodology. Reviews the Implementation Plan.

Path Forward

Plan Documentation

The UMCS Workgroup will review and refine the Implementation Plan. The plan will be a living document and coordinated with other interested and involved parties including those listed under the Support Structure. The UMCS workgroup reviewed the initial draft Plan on 27 February 2007.

Select UMCS

Fort Bragg needs to select/procure a basewide single-vendor UMCS to serve as the front-end (brain) for all their BAS systems. This is a three step process.

1. Define/Specify UMCS. The UMCS Workgroup must edit the UMCS requirements in the generic "UMCS and Systems Integrator RFP/SOW"[*] contained in the "IMCOM LONWORKS® Building Automation Systems Implementation Plan" and edit UFGS 25 10 10 to include [Fort Bragg] specific requirements. In doing so the Workgroup needs to make sure the RFP/SOW and UFGS 25 10 10 include [Fort Bragg's] desired UMCS requirements, features, functions, and capabilities, particularly those listed in Goals and BAS Description portions of this (Fort Bragg's) Implementation Plan. The Workgroup will need to coordinate with and include [Fort Bragg] DOIM/IT-related UMCS requirements (need for IP network drops, providing static IP addresses, etc.).

2. Define/Specify System Integration Services and Support Services. (This can be considered integral to the above step). The UMCS Workgroup must edit the UMCS requirements in the generic "UMCS and Systems Integrator RFP/SOW" contained in the "IMCOM LONWORKS® Building Automation Systems Implementation Plan" and edit UFGS 25 10 10 to include [Fort Bragg] specific requirements. The UMCS Workgroup must identify SI services/requirements and related support services.

3. Procure UMCS and SI Services. The UMCS Workgroup must identify an approach to procure the single vendor basewide UMCS along with SI services. In the case of SI services, one option is to award an SI contract independent of the UMCS contract where the SI contract is for a long term such as 5 years where a single entity performs all SI services as new buildings/control system are installed/constructed. Another option is to include SI services requirements in each new building-level DDC system contract where each building-level Contractor is responsible for system integration (where the Contractor may choose to do the SI him/herself or may hire whomever installed the UMCS).

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[*] RFP = "request for proposal."

Some notable and miscellaneous issues/tasks related to the above steps include:

- Make sure that the items listed in the Goals and BAS Description portions of this Plan are incorporated into contract documents.
- Develop LONWORKS® Points Schedules. Identify and show mandatory and optional SNVT-related points. Include chillers and boilers. Consider standard SNVT naming convention. Consider standard sequence of control. CERL will take the lead on this.
- Identify arrangement for potentially embedding SI maintenance staff with OMD.
- NCT update methodology. Automatic versus manual updates of LNS database.
- O&M tool options such as personal digital assistant (PDA) or portable LDP with TP/FT-10 dongle.
- Require SI to monitor building usage and ratchet down when troops are deployed.
- Division of responsibility between the UMCS/DDC/SI contractors and DPW/OMD
- Compare requirements to Fort Hood contractual arrangement.
- All PCs may be transitioning to dumb terminals. What is the impact?

Integrate Existing LONWORKS® Buildings

The UMCS Workgroup will consider the need and technical potential for connecting existing LONWORKS® buildings into the BAS (non- LONWORKS® buildings are a lower priority and will be considered by the Workgroup at a later date on a case-by-case basis). To this end, the UMCS Workgroup will assist in the execution of a Contract being awarded by Savannah District (SAS) to obtain external assistance where the contractor will survey existing BAS elements to identify existing LONWORKS® controls and local control contractor support capabilities as part of identifying implementation requirements/approach. As part of this, the UMCS Workgroup will identify buildings to be surveyed on a priority basis where mini-plants will have high priority as will new buildings and those with a large footprint. The SAS contractor will assess the potential and cost for pulling local control system(s) into the basewide UMCS. A rough estimate is about $2000 to provide and install a CEA-852 router under the assumption that the IP network is available, the TP/FT-10 building control network exists and does not need to be extended, and the building control system contains

LNS compatible devices including LNS-plug-ins and a current LNS data-base. The Contractor will develop SOW requirements to perform the integrations.

Savannah District Coordination

The UMCS Workgroup will coordinate with Savannah District on design and specification requirements for future Operations and Maintenance, Army (OMA) and MILCON projects connecting into the installation wide BAS. One issue is that current and future MILCON does not support running fiber to the mechanical rooms or connecting to existing installation systems. The installation has smart buildings that do not have any place to send their data.

IDG Update

The UMCS Workgroup will incorporate BAS requirements into the Installation Design Guide (IDG). Of particular interest is the UFGS 23 09 23 guide specification, which contains various designer options/selections that will impact features and functions of installed DDC systems. These options should be reviewed by the DPW so that the DPW and particularly the maintenance staff have an opportunity to provide input to system design and specification. These preferences should be documented in the IDG. Many of these UFGS 23 09 23 options/selections are specified by showing the required functions in a Points Schedule drawing where this drawing is referenced in UFGS 23 09 23. The IDG might include these drawings.

On Site Seminar

The UMCS Workgroup will assist with and participate in an on-site training and coordination seminar conducted by ERDC-CERL, SAS, and HNC to help further define the Implementation Plan.

UMCS and DDC Training

The UMCS Workgroup will identify training needs and a strategy for obtaining needed training such as including Fort Bragg specific training requirements in construction contracts and in the UMCS/SI RFP/SOW described under "Select UMCS."

BAS/DDC System Acceptance Methodology

The UMCS Workgroup will define a BAS building-level DDC system acceptance methodology checklist/procedures. The acceptance process will include design review by DPW/OMD along with procedures for construction inspectors and DPW to help ensure that all construction projects comply with the requirements of the BAS.

Energy Conservation Investment Program (ECIP) and Other Funded Support

The UMCS Workgroup will identify and seek funding support for the Fort Bragg BAS. This includes developing an FY09 ECIP proposal in support of the basewide BAS.

Appendix I: UFGS 23 09 23 LonWorks Compliance Assessment Tool Checklist

#	Priority	Category	Para #	Specification Requirement	Limited Test: Submittals Only	Detailed Test: Network Configuration Tool
1	High	General	1.4.1.a	Control system shall be an open implementation of the CEA-709.1B communications protocol using LonMark Standard Network Variable Types	Review Points Schedules, inspect devices for SNVT variables with SNVT type identified. Look for any UNVTs on the Points Schedule (or any UNVTs for points that are used on the controller). UNVTs are not in compliance with the intent of the specification.	Review LNS database, inspect nodes for SCPT configuration parameters and SNVT variables. Check for variable bindings between Scheduler and Equipment nodes of SNVT state_occupancy. Check for SNVT HVAC_occupancy exposed on equipment nodes. Check for UNVT
2	High	General	1.4.1.b	LNS services shall be used for all network management. A copy of the LNS database shall be submitted to the project site.	Ensure LNS database submitted as part of record-drawings.	Restore the submitted LNS database to the network configuration tool. Open the database and inspect the nodes. Verify the nodes match the submitted equipment lists.
3	High	General	1.4.1.f	All necessary documentation, configuration information, configuration tools, programs, drivers, and other software shall be licensed to and otherwise remain with the Government such that the Government or their agents are able to perform repair, replacement, upgrades, and expansions of the system without subsequent or future dependence on the Contractor.	Review submitted As-Built documentation and software provided by contractor. Ensure that plug-in and programming software is provided for all controllers detailed in Record Drawings and points schedules. Ensure that proof of software licensing listing Govt as owner exists in the submittal package.	
4	Med	Other/Misc	1.8.f	The HVAC control System Operation and Maintenance Instructions shall include printouts of configuration settings for all devices.	Review record drawings for controller printouts consisting of a printed table of each controller's configuration parameters	
5	High	DDC Hardware	1.12.1.b	The Building control network backbone shall be a TP-FT10 network if a backbone is utilized.	Review network riser diagram. Ensure that only FT-10 routers and devices exist in the riser diagram except the BPOC, which should be a IP to FT-10 network device.	
6	High	DDC Hardware	1.12.2.a	The backbone shall have no control devices connected to it. Only CEA-709.1B Routers	Review riser diagram and verify no control devices exist on the backbone	
7	Med	DDC Hardware	1.12.2.b	The backbone shall be installed such that a router at the Building Point of Connection (BPOC) location may be connected to the backbone.	Review record drawings and verify that backbone is located in the BPOC location	
8	High	DDC Hardware	1.12.2.c	The local control bus shall use CEA-709.1B over a TP/FT-10 network in doubly-terminated bus topology in accordance with CEA-709.3	Review record drawings and verify that local control bus has network layout documented with location of terminators identified. The TP/FT-10 network should be a single strait bus with no single drops exceeding 3 feet. Termination should occur at each end of the local control bus.	
9	Med	DDC Hardware	1.12.2.d	The local control busses shall be installed such that no node(device connected to the control network) has more than two CEA-709.1B Routers and CEA-709.3 Repeaters (in any combination) between it and the backbone, including the router connected to the backbone.	Review riser diagram and ensure that no channel is configured in such a fashion that more than two CEA-709.1B routers and repeaters exist between the backbone and the nodes	

#	Priority	Category	Para #	Specification Requirement	Limited Test: Submittals Only	Detailed Test: Network Configuration Tool
10	High	DDC Hardware	2.4.1.1	CEA-709.1B Routers (including routers configured as repeaters) shall meet the requirements of CEA-709.1B and shall provide connection between two or more CEA-709.3 TP/FT-10 channels.	Review product data sheets and ensure that all installed routers are CEA-709.1B certified.	
11	Med	DDC Hardware	2.4.2	Gateways shall perform bi-directional protocol translation from one non CEA-709.1B protocol to CEA-709.1B. Gateways shall incorporate exactly two network connections: one shall be for connection to a TP/FT-10 network in accordance with CEA-709.3 and the second shall be as required to communicate with the non-CEA-709.1B network.	Review product data sheets and ensure that all installed gateways incorporate one TP/FT10 network port and one proprietary network port. Review riser diagram and confirm that proprietary network connection and TP/FT10 network connections exist	
12	High	DDC Hardware	2.14.1.c	All DDC hardware shall incorporate a TP/FT-10 transceiver in accordance with CEA-709.3 and connections for TP/FT-10 control network wiring. It shall not have connections to any other network media type and it shall communicate via the CEA-709.3 protocol only.	Review product data sheets and ensure that all installed nodes incorporate a TP/FT10 transceiver. Review Record drawings device details to determine the TP/FT10 transceiver is set for operation if jumper settings are required. Note: Transceiver designation may be TP/FT-10, FT-10, FTT-10, or FTT-10A depending upon manufacturer.	
13	High	DDC Hardware	2.14.1.h	It shall have all functionality specified and required to support the application (Sequence of Operation or portion thereof) in which it is used, including but not limited to: (1) It shall provide input and output SNVTs as specified and required to support the sequence and application in which it is used. (2) It shall be configurable via standard or user-defined configuration parameters (SCPT or UCPT), SNVT network configuration inputs (NCI), or hardware settings on the controller itself as specified and as required to support the sequence and application in which it is used.	Review points schedules and product data sheets. Inspect nodes for SCPT configuration parameters and SNVT variables. Verify that points defined in sequence and points list are represented by SNVT variables in the point schedules. Verify that configuration parameters as required for the sequence of operation are identified	Review LNS database, inspect nodes for SNVT configuration parameters and variables. Verify that points defined in sequence and points list are represented by SNVT variables in the LNS database. Verify that configuration parameters as required for sequence of operation are identified.
14	High	DDC Hardware	2.14.3.a	ASCs shall be LonMark Certified.	Review product data sheets and ensure LonMark certification status	
15	High	DDC Hardware	2.14.b	Unless otherwise approved, all necessary Configuration Parameters and network configuration inputs (NCIs) for the sequence and application in which the ASC is used shall be fully configurable through an LNS plug-in. This plug-in shall be submitted as specified for each type of ASC (manufacturer and model). (Note: configuration accomplished via hardware settings does not require configuration via plug-in)	Ensure plug-in application is provided for each ASC type with software submittal, contact the submitting contractor for file names for clarification if required.	
16	Med	DDC Hardware	2.14.3.c	Local Display Panel (LDP): The Local Display Panel shall be an Application Specific Controller (ASC) with a display and navigation buttons. It shall provide display and adjustment of SNVT inputs and SNVT outputs as shown.	Ensure that the LDP communicates via LonWorks protocol. If the contractor provides an LDP that is embedded in a GPPC it shall permit access to display and adjustment of SNVTs that are external to the GPPC that the LDP exists in. Ensure plug-in and project application(s) are included in software submittal.	

#	Priority	Category	Para #	Specification Requirement	Limited Test: Submittals Only	Detailed Test: Network Configuration Tool
17	High	DDC Hardware	2.14.4.b	All programming software required to program the GPPC shall be delivered to and licensed to the project site as specified. Copies of the installed GPPC application programs as source code compatible with the supplied programming software shall be submitted as specified. The submitted GPPC application program shall be the complete application necessary for the GPPC to function as installed and be sufficient to allow replacement of the installed controller with a GPPC of the same type.	Ensure GPPC application and source code files are provided with software submittal. Contact submitting contractor for details concerning applications and source code files if the reviewer is unfamiliar with the vendor's products.	
18	Med	DDC Hardware	3.2.4.a	Each gateway shall communicate with and perform protocol translation for non-CEA-709.1B control hardware controlling one and only one package unit or monitor only on multiple units	Review record drawings and riser diagrams to ensure third party networks are not employed and gateway communicates with only one unit or is monitor only on multiple units.	
19	High	DDC Hardware	3.2.4.b	Non-CEA-709.1B control hardware shall not be used for controlling built-up units.	Review record drawings and riser diagrams to ensure that gateway communicates only with package unit controller, not third party external controls	
20	High	DDC Hardware	3.2.4.c	Non-CEA-709.1B control hardware shall not perform system scheduling functions.	Review device points schedules to ensure scheduling not performed by the Gateway device. Ensure output (NVO) SNVT occupancy and mode are status points for equipment on the proprietary port of the gateway.	
21	High	Scheduling	3.4.2.2	The System Scheduler functionality shall reside in either a piece of DDC Hardware dedicated to this functionality or in the DDC Hardware controlling the system AHU. A single piece of DDC Hardware may contain multiple System Schedulers. A unique System Scheduler shall be provided for: each AHU including it's associated Terminal Units, and each stand-alone Terminal Unit (those not dependent upon AHU service)[or group of stand-alone Terminal Units acting according to a common schedule].	Review As-Built Documentation to determine the location(s) of the default scheduler(s). The default scheduler may reside in one or more pieces of dedicated hardware, it may reside in certain brands of ANSI/CEA-852 LON to IP routers, or in a GPPC schedule module. Once the scheduler is identified, if scheduling is performed in anything other than a GPPC, confirm a different output SNVT of SNVT_occupancy exists for each major system in the facility by reviewing the points schedules.	
		Scheduling		Each System Scheduler shall provide the following functionality:		
22	High	Scheduling	3.4.2.a	Scheduled Occupancy Input: Accept network variable of type SNVT_occupancy (as defined in the LonMark SNVT List). Input shall support the following possible values: OC_STANDBY, OC_OCCUPIED and OC_UNOCCUPIED.	Review Network variable list of the scheduler and identify an input SNVT_occupancy point for each system as defined by the project scope of work. Identify the correct range (OCC_STANDBY, OCC_OCCUPIED, OCC_UNOCCUPIED) listed on points schedule.	
23	Med	Scheduling	3.4.2.b	Occupancy Override Input: Accept network variable of type SNVT_occupancy (as defined in the LonMark SNVT List). Input shall support the following possible values: OC_STANDBY, OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL.	Review Network variable list of the scheduler and identify an override input SNVT_occupancy point for each system as defined by the project scope of work.	

#	Priority	Category	Para #	Specification Requirement	Limited Test: Submittals Only	Detailed Test: Network Configuration Tool
24	Med	Scheduling	3.4.2.c	Space Occupancy Inputs: For systems with multiple occupancy sensors, accept multiple inputs of network variable type SNVT_Occupancy (as defined in the LonMark SNVT List). Input shall support the following possible values: OC_OCCUPIED, OC_UNOCCUPIED, and OC_NUL. For systems with a single occupancy sensor, accept a network variable input of type SNVT_Occupancy or a hardware binary input (BI) indicating the space occupancy status as Occupied or Unoccupied.	Review Network variable list of the system controller and identify Sensor(s) input(s) SNVT_occupancy point for each occupancy sensor as defined by the project scope of work.	
25	High	Scheduling	3.4.2.d	Air Handler Occupancy Output: For a System Scheduler for a system containing an air handler, output one or more SNVTs indicating the desired occupancy status as one of the following possible values: Warm-Up-Cool-Down (when required by the AHU Sequence of Operation), Occupied and Unoccupied.	Review Scheduler Output Network variable list. Ensure output SNVT_occupancy point exists for each controlled system. Ensure Range of variable includes only the following values: OC_STANDBY, OC_OCCUPIED, and OC_UNOCCUPIED	
26	High	Scheduling	3.4.2.d	Terminal Unit Occupancy Output: For a System Scheduler for a stand-alone terminal unit, [a group of stand-alone terminal units acting according to a common schedule,] or a group of terminal units served by a single air handler, output one or more SNVTs indicating the desired occupancy status as one of the following possible values: Occupied and Unoccupied.	Review Scheduler Output Network variable list. Ensure output SNVT_occupancy point exists for each controlled system. Ensure Range of variable includes only the following values: OCC_OCCUPIED and OC_UNOCCUPIED. Note: The possibility exists that the air handler will pass the occupancy command to the terminal units.	
27	High	Scheduling	3.4.2.e	Default Schedule: Incorporate a 24-hour 7-day default schedule as shown on the drawings which may be activated and deactivated by the System Scheduler Logic.	Review Scheduler default schedule parameters in as-built documentation and verify that the default schedule is set for 24-hour 7-day operation.	
28	High	Other/Misc	none	BPOC location and network drop IP issues	Determine if the target building has DOIM IP network installed in the building. If the IP network is currently in the building then plans should show extension of an IP drop from the DOIM IP closet to the BPOC location. If the IP network does not exist in the building then the plans should show the supplying of the IP network infrastructure to the target building. DOIM will need to help plan/execute the installation of the IP network into the target building.	

REPORT DOCUMENTATION PAGE

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. ABSTRACT

Army Installations often expand their use of digital control systems for heating, ventilating, and air conditioning and other mechanical and electrical building systems on a building-by-building basis. Associated control systems are installed under separate contracts by different contractors resulting in intra-system incompatibilities. The implementation of multi-vendor Open Building Automation Systems (BASs) is meant to overcome such incompatibilities; however BASs can present their own technical and administrative (including contractual) challenges. This report defines a methodology for the development and execution of a basewide Open Building Automation System (BAS) implementation plan based on LonWorks ® technology and American National Standards Institute (ANSI) communications standard 709.1 where the BAS consists of a basewide Utility Monitoring and Control System (UMCS) that is interoperable with multi-vendor LonWorks ® direct digital control (DDC) systems.

15. SUBJECT TERMS

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